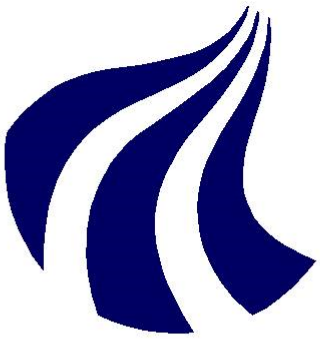

AALBORG UNIVERSITET
ESBJERG

Developing indicators to be used for a fire related risk evaluation of buildings

semester 10

M.Sc. in risk and safety management

Master Thesis

January 7, 2016

AALBORG UNIVERSITY
STUDENT REPORT

Title:
Developing indicators to be used
for a fire related risk evaluation of buildings

Theme:
Master Thesis

Project Period:
Fall Semester 2015

Project Group:
RISK4-1-F15

Participants:
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Copies: 1

Page Numbers: 142

Date of Completion:
January 7, 2016

Abstract:

The motivation for carrying out this project is that there was a need for a way for building owners to be able to prioritize their building portfolio such that the most important building for the business can be found and fire & business impacts can be mitigated in the most effective manner.

The problem is solved by identifying potential fire & business impact indicators using three methods. Some of the identified indicators are analysed by hypothesizing the indicators which are then turned into theoretical variables by the use of risk influence factors. Lastly, the indicators are made operational by developing measures for them such that the fire & business impact of a building in a given business can be measured on and compared to other buildings in order to prioritize time and resources for mitigation efforts. These measures are called risk scores and enable the indicators to be used in a risk evaluation to create a risk picture of the buildings being evaluated.

The results are that five fire indicators were made fully operational and two partially operational. Furthermore, five business impact indicators were made fully operational. Safety measures were discovered and could possibly be used as risk reduction indicators on the risk scores the fire & business impact indicators give. It was concluded, that the indicators could be made more accurate with increased access to data which would also allow to develop more indicators.

AALBORG UNIVERSITY
STUDENT REPORT

Titel:
Udvikling af brand relaterede indikatorer til brug ved risiko evalueringer af bygninger

Tema:
Kandidatspeciale

Projektperiode:
Efterårssemester 2015

Projektgruppe:
RISK4-1-F15

Deltagere:
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Finn Buus Steffensen
Rasmus Würtz Møller

Oplagstal: 1

Sidetal: 142

Afleveringsdato:
January 7, 2016

Abstract:

Motivationen for at udføre dette projekt baserer sig på et identificeret behov om at bygnings ejeres mulighed for at prioritere bygninger efter deres vigtighed ud fra brand og dens effekt på virksomheden, for derved at kunne lave målrettet forebyggelse.

Opgave løsningen blev udført ved at identificere potentielle indikatorer for brand og den mulige effekt, ved hjælp af brainstorms, interviews og litteratur undersøgelse. Nogle af disse indikatorer blev udviklet til indikatorer ved opstille hypoteser og teorier for hvordan de har en indvirkning på risikoen. Til sidst blev indikatorerne udarbejdet med numeriske værdier for at gøre dem operationelle, for derved at kunne sammenligne og prioritere bygninger med henblik på effektiv tid og ressource håndtering. Disse værdier kaldet risiko score kan bruges til, at evaluere risikoen og etablere et risiko billede a virksomhedens bygninger.

Dette resulterede i at fem brand indikatorer blev udarbejdet til fuldt operationelle indikatorer og to der delvist blev. Yderligere blev der udviklet fem effekt indikatorer, som alle blev gjort operationelle. Derud over blev også opdaget at sikkerheds indikatorer kunne være potentielle tilføjelser til reducering af risikoen. Det blev konkluderet ud fra projektet, at med bedre data grundlag, ville det være muligt at udvikle eventuelt flere indikatorer.

Preface & Acknowledgements

This report, "Developing indicators to be used for a fire related risk evaluation of buildings" is written by group RISK4-1-F15 as an M.Sc thesis of 30 ECTS points on the 10th semester at the Faculty of Engineering and Science, Risk and Safety Management, Aalborg University, Campus Esbjerg. The report has been written in the period from 1st of September 2015 until 7th of January 2016. This project has been carried out in collaboration with Niras A/S in their risk and safety department where Finn Buus Steffensen and Rasmus Würtz Møller have acted as external supervisors.

This report uses the Harvard referencing style for the referenced sources in the bibliography. In-text referencing is shown as a number in squared brackets [X] and refers to the corresponding reference in the bibliography, quotes are between quotation marks. Tables and Figures are numbered according with the chapters, where the first number symbolizes the chapter number and the second number is the figure number within the chapter. With the copy of the report that is handed in to the university a CD is attached with the recorded interviews, copies of some of the research documents, calculations for the indicators and a digital copy of the report.

We would especially like to thank one of our supervisors, Lars Schiøtt Sørensen for giving us tremendous feedback throughout the process of writing this report, his substantial knowledge and experience with fires came to good use many times. Our supervisors at AAU Esbjerg, Kristian Breum Ølgaard and Lars Damkilde get sincere thanks for keeping us on the right path and pointing us in the right directions when needed.

A big thank you goes out to the external supervisors and the team of experts at Niras Risk & Safety for guiding us though this process and always being available for us to bounce ideas and questions of. Furthermore, we would like to thank the interviewees Jesper Scott Johnsen, Flemming Damholt, Ane Prehn Meyland and Lars Æbeløe-Knudsen for donating their time and experience to further the progress of this project. Kim Skafte Pedersen gets a special thank you for donating his lunch time for a conversation and for introducing us to Lars Æbeløe and Jesper Scott.

Last but certainly not least, we would like to thank Peter Lassen Bek and Anne Sønderskov Nielsen for making time in their schedule to accommodate us and sharing their knowledge of the insurance businesses.

Aalborg University Esbjerg, January 7, 2016

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Contents

Chapter 1

Introduction

Structural fires are an enemy to your business! The reason for that statement is that structural fires are one of the event that businesses may never recover from, although this mostly applies to small and medium sized companies [1]. The estimation for the recovery is that 43% will never open again and 51% of those who do open will close within the following two years [2]. This emphasises that even though fires are a low frequency occurring event [3] it should not be neglected due to its high impact. This impact can be seen from the insurance companies as the cost from fires are very high, with almost 3.2 billion DKK in fire damages every year within Denmark [4]. This is why it is in the interest for both insurance companies and the business owner to conduct risk assessments in order to reduce and/or eliminate the risk of fires occurring and/or its impact.

When conducting an risk assessment of buildings it often involves a time consuming inspection of the building in order to determine the condition of it and to identify possible failures that could lead to a fire event. This is a very detail oriented approach and as implied it requires an on site inspection, but what if an risk assessment is required for multiple buildings for a business with a large building portfolio, which building should be assessed first? This implies that there is a need for establishing a preliminary risk evaluation picture for individual buildings of the whole building portfolio, which could be used to prioritize which buildings to prioritize first. This is a demand that has been observed, that especially consultant- and insurance companies are looking for in order for them to prioritize time and resources for inspections on the buildings that have the highest risk exposure and thereby also meet their customers needs.

In order to make a risk evaluation of the fire related risks of a building it would be necessary to define what fire threats it could be measured on to state the level of fire related risks that a building is exposed to. Furthermore, if the intention with the risk evaluation is that it is preliminary, it should emphasise that the evaluation can be redefined when more substantial knowledge is achieved by means such as inspections. With that definition it could be said that the input for the risk evaluation should be an indication of what fire threats could tell us about the fire risk of a building. In other words, it means that the inputs for the risk evaluation are defined as Fire Indicators (FI) that are developed from fire threats and can be used to measure the fire related risks of buildings.

From a risk evaluation point of view, the specification of an FI as an input for a risk evaluation of a building would from a technical risk approach not cover enough to make a full risk evaluation [5]. This is due to that risk is defined as the correlation between cause and

consequence of an event, which is shown in the Bow-Tie diagram in Figure 1.1 where there is a before- and an after state of a risk event where the event in this case is a fire event.

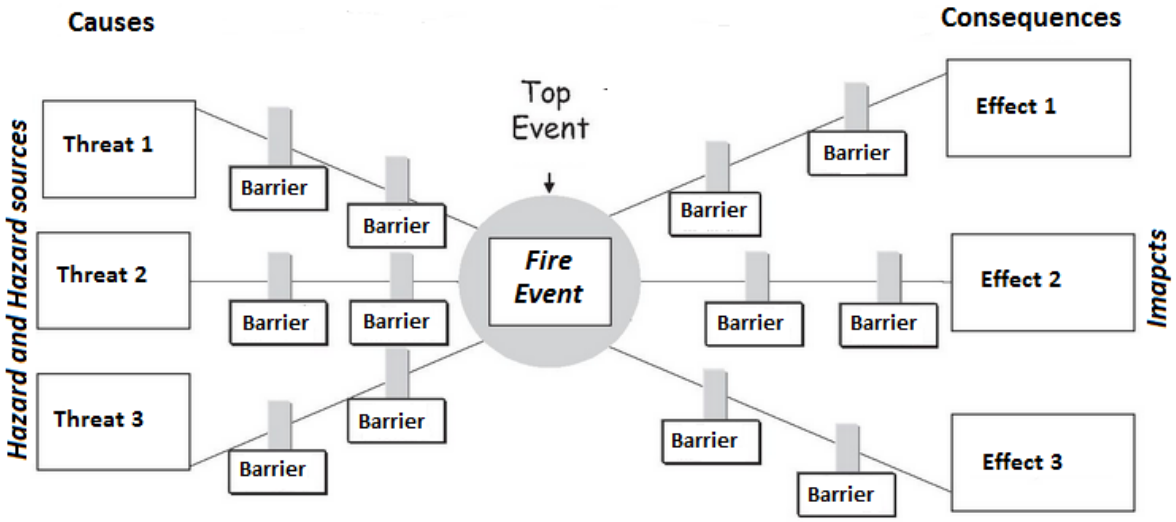

Figure 1.1: Evaluation of risks for buildings are confined in the threats it is exposed to, combined with the possible effect the event would have [6].

From the Bow-Tie diagram it should be understood that the left side refers to the causes for the risk, the FI, where the right side of the Bow-Tie is what is missing from the risk evaluation. This side states what the effect from the fire event could be. An evaluation only based on the building's exposure to a fire would not fully define what could happen when the fire event is realized. That would probably be just as important to know when evaluating a building's fire related risks in order to prioritize one from another, due to that there might be more at stake for the business owner. Therefore, it is necessary to develop an indicator for this side of the bow-tie to add to the risk evaluation of a building. This indicator will be called Business Impact Indicators (BII) and define the effect that the event would have on the business.

What can also be read from the Bow-Tie is that the input for an event is made up from the causes which are represented by individual threats exposures that posses a fire risk to a building. The output from the fire event is determined in consequences, which is represented in the effect that the fire event would have on a business. It could therefore be implied that the parameters that the indicators could be developed from are represented in the threats that buildings are exposed to and the the effect that would follow.

The intention with the finalized risk evaluation is that it is supposed to assist building owners that have a responsibility to manage more than one building, by establishing a preliminary risk picture for all the buildings in the portfolio and rank them according to which one has the highest risk. This states that this thesis is determined to develop indications to measure the buildings criticality in relation to these two input, all in order to define the risk level of the individual buildings. In the following section there will be a presentation of each of these two parameters.

1.1 What is an indicator?

Before going deeper into the two inputs from which the indicators are developed from, it is necessary to have an understanding of what an indicator is and what it can articulate. Most companies use indicators to measure if they are achieving their goals and one of the more familiar indicator might be the Key Performance Indicator (KPI). This is an indicator defined as "a metric which is used to determine how the performance is against the business objective" [7]. Key Performance Indicators are used by organizations to define and measure progress toward organizational goals [8], [9]. However, there are also indicators used to measure the performance towards risk and safety aspects. These are named Key Risk Indicators (KRI) and Safety Performance Indicators (SPI) and are presented in Table 1.1.

Indicator	Definition	Where used
Safety Performance Indicator (SPI)	Measure with objectivity the safety performance of health and safety aspects and provides early warnings [10], [11].	The International Atomic Energy Agency, has from the end of the 1980's been developing Safety Performance Indicators to ensure operational safety performance for nuclear power plants [12]. They have also been applied in other fields such as offshore [13].
Key Risk Indicator (KRI)	A metric used to signal an increased risk exposure and is used in different areas of the whole enterprise [14].	Because of its generalized application it is found useful in various areas, but is commonly seen in reference to operational risks [14].

Table 1.1: Definitions of risk and safety indicators that are used today.

Based on what is now known about indicators that are used today it can be said that they all tend to measure how the performance is against a specific target, which means that indicators have to be measurable. The measurement of the KRI and SPI are used to give a signal of how the performance towards the targets is proceeding. However, since one of the definitions of performance indicators is that they are made up from metrics, it highlights that there might be indicators that are diversified in how they measure performance. One of the more broader definitions of indicators is that they are a measurable variable that describes the conditions of a broader phenomenon [15].

When developing indicators it should be known that there are mainly two types of indicators being used today, leading and lagging indicators [16]. The leading indicators are predictive measures that can help forecast the future risk occurrences. Where the lagging indicators are measures based on historical data that identify risk related trends [16], [17]. Leading and lagging indicators are often described with the use of the Swiss-cheese model seen in Figure 1.2. Here, the cheese slices represent the leading indicators, these indicate that a risk is about to occur, they are also referred to represent the risk control systems in place to stop an event from occurring. Where the lagging indicators reveal the holes in the cheese slices, the risk control systems, through the occurrence of events and when discovered action can be taken to prevent re-occurrence [18] [11].

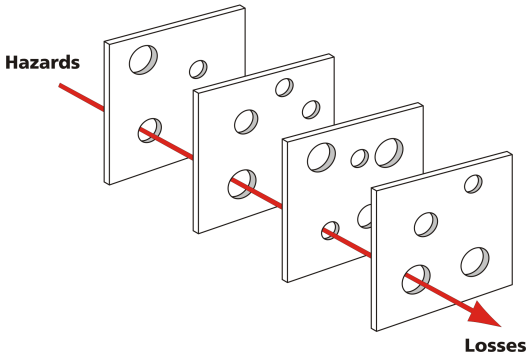

Figure 1.2: The Swiss cheese model where the cheese slices represent the leading indicators and the lagging indicators reveal the holes in the cheese slices which can be used to take action. [19]

The indicators that are looked for are supposed to state which buildings are less resilience towards a fire related risk and what makes the building important to the owner if lost to a fire. These risk indicators therefore have to state how the individual building is performing against a fire. Leaving the making of the performance measurements to be based on building information that indicates a fire might occur in the future, hence the leading indicator, or that the performance of the building amplifies a lag in safety performance.

1.2 Fire indicators for buildings

The first indicator in the risk evaluation are the fire indicators which are supposed to determine what fire related risks the building is exposed to. These indicators can be found in various ways, for example one could identify the fire related hazards presented in a building which would give an indication of why a fire event could occur and what the volume of it could be. This approach would use the basic element for what makes a fire event to determine what the possible hazards elements in a building would expose this risk [20]. This approach could be based on the core elements of the fire triangle, which can be seen in Figure 1.3.

Figure 1.3: The triangle shows three conditions, Oxygen, Heat and Fuel that are needed in order for a fire to take place. The triangle is more commonly known as the fire triangle [24].

With the fire triangle it should be read that the three hazards are the exposures that make the building more likely to have a fire and that if one of the three hazards are taken out of the equation then a chance of a fire occurring is eliminated. These hazards are conditionally based, meaning that a fire event would only happen if the circumstances provide these three hazards in the right volumes and in a combination of each other, which also emphasizes that

the activities that put these hazards in the same place could be another hazardous factor to take into account.

Another place to look for fire indicators would be to look at historical trends to see how fires have occurred in the past and thereby see if that can represent any logical conclusions to why fires have occurred, which could be possible causes for an event in the future. One of the misrepresentations in this approach would be that trends might be changing during the years due to development of technologies and because of mitigation actions that are made to eliminate the risk. As an example, it can be seen that in some of the developed countries represented on the graph in Figure 1.4 that the number of fires have been decreasing for the countries Denmark, USA and the UK. [1]

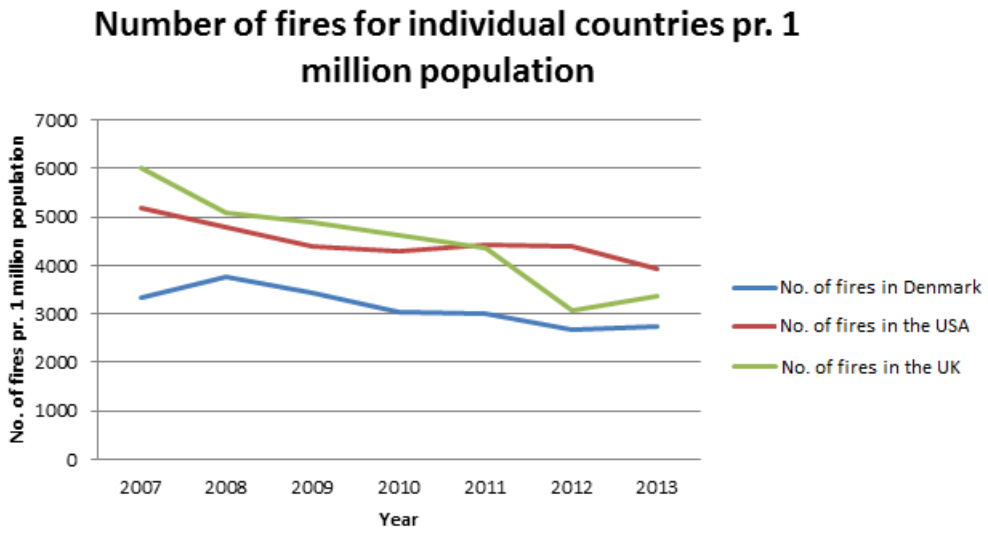

Figure 1.4: The graph shows how the number of fires from 2007 to 2013 have been in Denmark, USA, and UK, and are measured in 1 million people.

Even though the number of fires in the aforementioned countries have been decreasing it could still be possible to identify trends to develop indicators from. The challenge though, would be to see if the risk exposures have changed and that is the reason for the decrease, because that would emphasis that there are no trends in the historical data. Based on this it could be useful in the chase for developing fire indicators to analyse fire statistics for fire trends and to guide such an analysis it could be interesting to see it in relation to the following questions:

- What have been the causes for fires?
- What can be said about the characteristics of fires that have occurred?
- What was the intensity of the fires that occurred?

The indicators that are developed from the identified threats that are supposed to measure the buildings performance against a fire event are one of the input to the preliminary risk evaluation. This preliminary risk evaluation can then be revised later when more substantial knowledge about the building has been obtained, which can be through inspections. This is why information used for indications of a buildings performance are based on easily accessible information that can be obtained without having to inspect the building. This definition can

[1] The numbers behind the graph can be found in sources [21], [22], [23], [25], [26] and [27]

question what easily accessible information actually is? The first and foremost understanding used in this project is that the information should obtained as a back office task.

With the scope, that the indicators should be based on easily accessible information, it raised the question of what information falls under this category. One thing that could be defined as easily accessible information is the building data that is monitored by the authorities. Such data could for example be the Building and Residential Registration (Bygnings- og Bolig Registreret, BBR), which is a registry of all buildings in Denmark that contains information about such as what the building is used for, what construction materials are used, the number of square meters and etc. [28].

This information is easily accessible due to that the data is available to the public and can thereby be obtained with minimal effort. Information about other easily found fire indicators could be found through a drawing of the building, which could give some knowledge about how the building is designed and what it is used for. This is assuming that the building drawings are available to the owner of the building.

It should be a little more clear after this section what fire indicators can be, how they are identified, what they should indicate and what kind of information they should be based on. In the next section the impact indicator is addressed and it will give some information about how the outcome of a fire event could be measured with regards to the impact.

1.3 The impact of a fire event

Another input to take into account when making a risk evaluation of a building is the effect that the fire event could have on the business if the building were lost. The impact from a fire would not only in the worst case scenario affect the business as a lost building but also as an important function for the business as well. With the knowledge of which buildings would be impacted the most, it would be possible to determine where the business is most vulnerable to a fire event.

With the knowledge of where the business is most vulnerable, it would know where to start mitigating or eliminating fire events from occurring. This would therefore emphasize that the severity of the business impact would be the motivational driver that a prioritization should be based on. For that reason, it is important to know what can indicate a business being vulnerable and what it is measured on, which leads to the need for business impact indicator knowledge.

The loss of a building does not only affect the business as lost values in physical items. It can also be a loss for the business as a system that creates values. Value creation is according to Michael E. Porter created through the business internal activities. These activities are divided into Primary- and Supporting activities, which can be seen in Figure 1.5 [29] and [30]. The value creation that Porter's Value Chain refers to, is the businesses ability to meet the customers needs as well as to make a competitive production, both of which give a competitive advantage. The primary activities are the activities where the inputs are transformed to outputs which are sold as services to the customer [29] and [30]. The supporting activities on the other hand are those that relate to the infrastructure that ensures the primary activities to be as effective as possible.

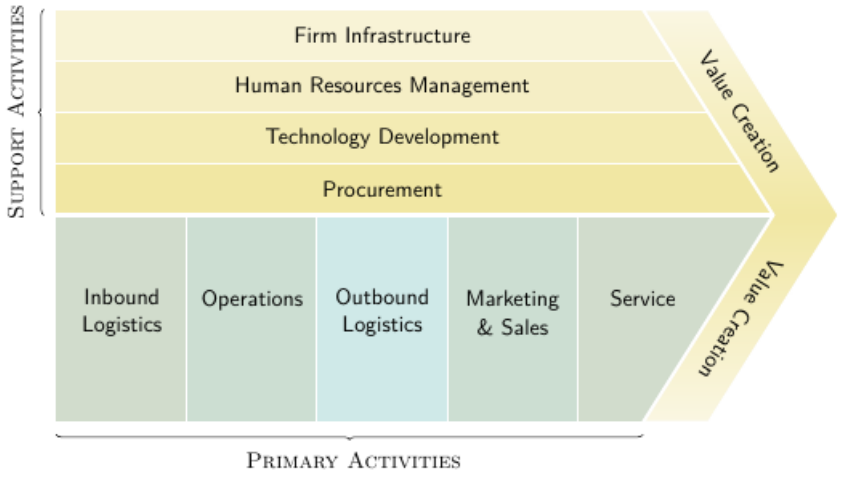

Figure 1.5: This Value Chain diagram divides the creation of values for a business into primary activities and supporting activities [29] and [30].

Figure 1.6 explains the individual activity definitions.

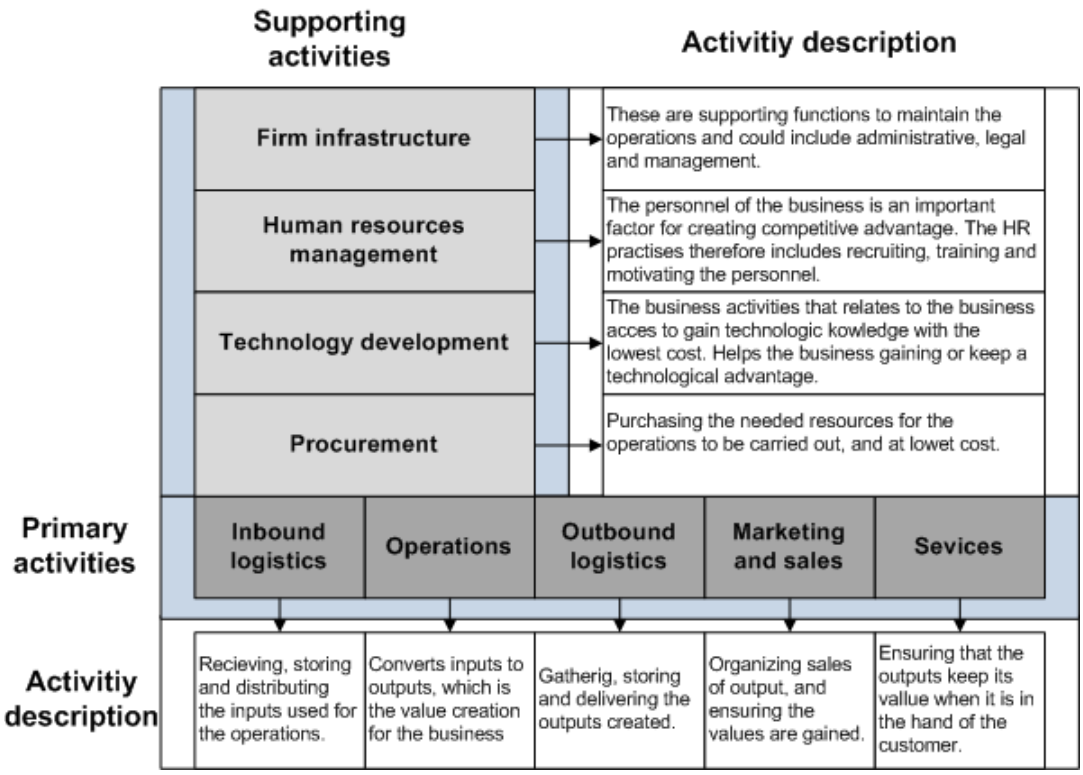

Figure 1.6: Definitions of the Primary- and Supporting activities of Porter's Value Chain [29] and [30].

Porter's Value Chain model explains that the impact to a business goes beyond the physical values the business has "today", to also include what it would create "tomorrow". The development of business impact indicators to be used in a risk evaluation of buildings is going to state how the building possesses a certain importance to a building owner and therefore has to be evaluated as a comparison to how it would affect the whole business.

Chapter 2

Problem formulation

The challenge introduced in the introduction was to make a preliminary risk evaluation based on indicators, such that building owners of multiple buildings can choose which one to prioritize when mitigating for fire events. This leads to the following chapter, where the problem will be specified from which a project will be carried out.

2.1 Research question

The problem that this project is going to handle, is about how to develop fire related risk indicators to be used in a risk evaluation of buildings in order to establish a preliminary risk picture of individual buildings.

It is the goal with the final risk evaluation that a given business owner, who uses these indicators in a risk evaluation, would be able to identify the most risk critical buildings and prioritize which one to start spending time and resources on, in order to reduce or eliminate the fire related risks. With this prioritization it is possible to prioritize time and resources on the most important risks of a business. The risk evaluation is based on indicators that are developed from the inputs for the threat exposure and effect impact on a building and the associated business. This lead to the following research question:

How can indicators be developed for a preliminary risk evaluation of fire related risks and be used to indicate which of multiple buildings is most risky to the business?

In the introduction chapter it was deduced that in order to make a risk evaluation of a given building, it requires a look at both sides of the Bow-Tie where the threat and the effect are represented. This emphasized that the indicators that are going to be developed would be made from indicators that expose a threat to the building and an impact that defines the effect it would have to a business. The indicators developed from the two inputs are called fire indicators for the threat and business impact indicators for the effect. From this breakdown of the research question, the following two sub-questions have been made:

1. What indicators can be used to determine the fire risk of a building?
2. What indicators can be used to determine the impact to a business from a fire?

   These two sub-questions call for an identification of the two previously defined inputs, that serve as indicators for a risk evaluation. In order to measure these two indicators

as an input to the risk evaluation there should be developed indicators for the identified threats and effects. In order to make the identified threat and effect results applicable in a risk evaluation it is necessary to develop indicator measurements for them. That is why the two previously mentioned sub-questions are related to the following underlying questions.

- How can the indicators be developed to prioritize one building over another using measurements?

  With this sub-question the purpose is to develop measurements for the identified indicators such that it is possible to state the risk score of a given building by using the indicators. This makes it possible to define how the indicators can be used in a risk evaluation of buildings which leads to the final sub-question.

3. How could the developed indicator/s be used in a risk evaluation of buildings?

With this last sub-question it should be possible to make a preliminary risk evaluation of buildings by combining the developed indicators. This evaluation would then not only be able to be used to define the fire risk of a building but also what the possible impact that follows a fire event could be. With this information it should be easier to prioritize one building from another.

2.2 Delimitation

The scope of the project is to develop indicators to be used to evaluate a buildings fire risks and for the impact the fire event would have on the business if a fire event were to happen. With such an evaluation it would be possible for the owner of multiple buildings to determine which of the buildings would be most important to reduce the fire risk on.

This is therefore limited to the types of buildings that are a part of a larger business with multiple buildings. This means that the application of the indicators would not be aimed for buildings with residential purposes, since they might not be the main users. This emphasizes that information as well as data used in this project would only represent public and business owned buildings or in other words, public and non-residential buildings.

The indicators for the fire risks of a buildings should be based only on what makes a fire risk for a building. This means that even though that fire can be the root cause for other events occurring, it would not be the intention of this project to concern that as a risk for the risk evaluation. This also includes smoke damages from the fire, water damages from extinguishing the fire and other similar sub events.

It is furthermore decided to limit the scope of which buildings the indicators will be applicable for, by only looking at Danish onshore buildings. The main reason for this delimitation is to avoid countries differences in constructing buildings, legislation, culture and climate which could skew the fire risks of a building. Also because that different laws, standards, rules and norms would be different from onshore and offshore structures. That being said, it could be possible that the developed indicators still could be applicable for offshore structures and buildings in other countries.

When it comes to developing fire indicators there also has to be distinguished in when an event is considered a fire event. A fire in this case is only determined a fire event if it has involved the response of the fire rescue services such as the Local Fire department (LFD).

This delimitation is made because it is assumed that the fires that the LFD were called to were those that can have potential to be big fires. This delimitation is made even though the data from the LFD only accounts for approximately 24% of all fire events [4].

The business impact indicators should be used to represent which buildings in a business are the most important when it comes to what the impact could be. It is therefore the objective that importance of a building is measured in how it would affect the businesses monetary values, because it is assumed that this is what makes the business run. Therefore, other areas of impacts such as people and the environment are excluded as representative measures for the indicators.

2.3 Outline

This section is an outline of the project report and is used to give an overview of the project steps that are carried out in order to achieve the goals set forth in the problem formulation.

The first step of this project is to establish a theoretical foundation from where the projects main methodologies are made to carry the project. This can be found in Chapter 3 where the risk evaluation process and how indicators are developed which are the two main themes for the whole project, are explained.

When the main methodologies are defined, the initiation of identifying indicators is the next step. This step will is carried out in Chapter 4 which includes the identified fire indicators as well as the business impact indicators, that could possibly be used.

Following the identification of the fire and business impact indicators, the analysis is carried out. In the analysis the selected indicators are analysed for why they can be used as indicators and after this step they are considered to be fully developed indicators. The step is divided into two chapters, chapter 5 and chapter 6 because of the difference in what the indicators represent and they therefore are analysed individually.

Chapter 7 is where the indicators are made operational for the risk evaluation. This means that the indicators that where analysed, are developed to be numerical measurements for the risk evaluation and will help prioritizing one building over another. Both the fire and the business impact indicators are carried out in the chapter because they are made for the same purpose, the risk evaluation.

Chapter 8 is where the developed indicators are implemented into how they could be practically used in a risk evaluation process. This step is where the measurements the indicators were assigned are made useful in the risk evaluation process.

Finally in chapter 9 the conclusion is presented.

Chapter 3

Methodology

In this chapter a comprehensive explanation of developing indicators for a risk evaluation of fires in buildings will be made. First of all, the intention is to describe the risk evaluation that the indicators are going to be developed for in order to create a better overview of where in the evaluation process the indicators are used in section, this is done in 3.1. After defining the methodology behind the risk evaluation, the next step is to define the methodology behind developing indicators, which purpose serves to give an understanding of how indicators can become useful measurement to measure performance, which is presented in section 3.2. Section 3.3.1 cover what processes were used to identify potential indicators.

3.1 The risk evaluation of indicators

As was described in the introduction, the focus of this project is to look at the threats and effects that can tell about a risk of a fire event and that they can be related to the input and outcome of the Bow-tie diagram, where the threat can be considered as the input and the effect the outcome in regards to the bow-tie. From the problem formulation it can be read that the purpose is to develop parameters that can be used as indicators, to point out the fire risk state of a given building. This means that there are going to be used two groups of indicators to establish a risk evaluation of a building, which is described next:

1. Fire Indicators (FI):

   The FI are indicators used as a covering term for the inputs shown as threats. These indicators are supposed to tell about the fire threat exposure that a given building gets exposed to and is based on underlying analysis of the threats, as to how they determine the severity of an event.

2. Business Impact Indicators (BII):

   The BII stand in relation to the outcome of consequences from the occurrence of a fire event. These indications determine the risk in relation to the effect or impact, that the worst fire scenario could have on a business, which is used to state the importance of the given building.

Since the two groups of indicators are based on the bow-tie diagram, they perfectly follow any risk assessment method, where the risk assessment is a product of a risk analysis and a risk evaluation. The risk assessment process is made up from three main steps as shown

in Figure 3.1. This particular assessment process is quite similar to the Probabilistic Risk Assessment (PRA) process that is used by the British Standard Institute (BSI), with the only deviation being that the cause analysis is defined as an analysis of frequency in the PRA process used by BSI. [31].

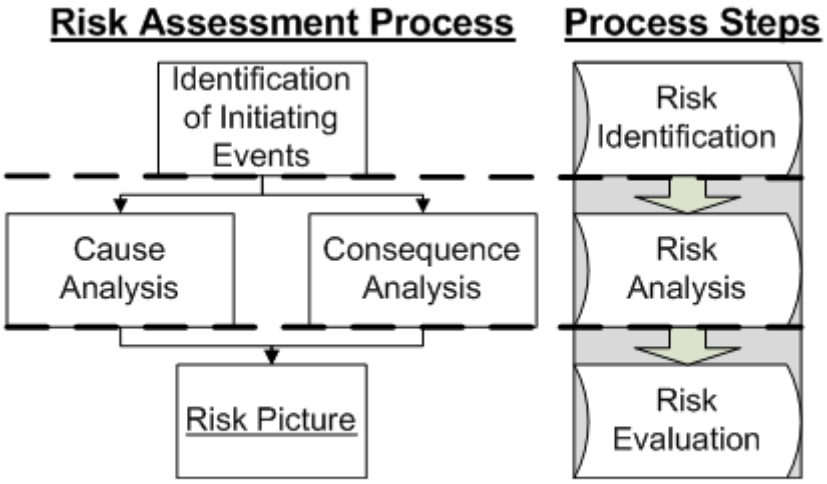

Figure 3.1: The breakdown of the risk assessment process and related steps [32].

In this process the risk evaluation process is understood as the process that can be carried out with the use of the developed indicators. Besides from that, this project is also structured through the risk evaluation process in terms of how the indicators are developed. The process is to identify the indicators and analyse the risks they represents which then are used to establish a picture of what risks they expose to the building and its business.

What can be taken from this risk assessment process is that in order to get to the risk evaluation step and establish a risk picture, the developed indicators should represent the above lying steps. What should also be taken from this process is that the FI are supposed to represent the cause analysis and the BII the consequence analysis since that is the definition gained from the Bow-tie diagram.

Before moving on to the section about the method used for developing indicators, the risk picture will be explained since that is the evaluation the indicators should be used for. The understanding of an risk evaluation is that in that step, the results from the previous steps, the quantitative or qualitative analysis, are compared in order to determine if the risk level is acceptable [33]. In this project there is no "fixed" acceptable risk level since the outcome of the risk evaluation is supposed to be used to compare buildings to establish which has the highest risk and could therefore be prioritized over the other buildings.

3.2 The development of indicators

In the pursuit of identifying threat and effects, upon which indicators can be developed it is important to describe how indicators become indicators. As was previously defined in the introduction, indicators should be measurable variables which can be used to describe the

performance against a certain target. Since the goal of this project is to develop indicators to be used in a fire risk evaluation of buildings, the method that is used is to achieve this is presented next.

The approach for developing indicators is that the indicators are based on a risk influencing factor, which is a factor for the risk that the measurement is going to be a description of [15]. The risk influencing factors in this project are defined as the factors that can describe the fire event of a building, in terms of what makes the building threatened by a fire and what the possible impact from it could be. Figure 3.2 is a recreation of a figure which shows the process of developing indicators.

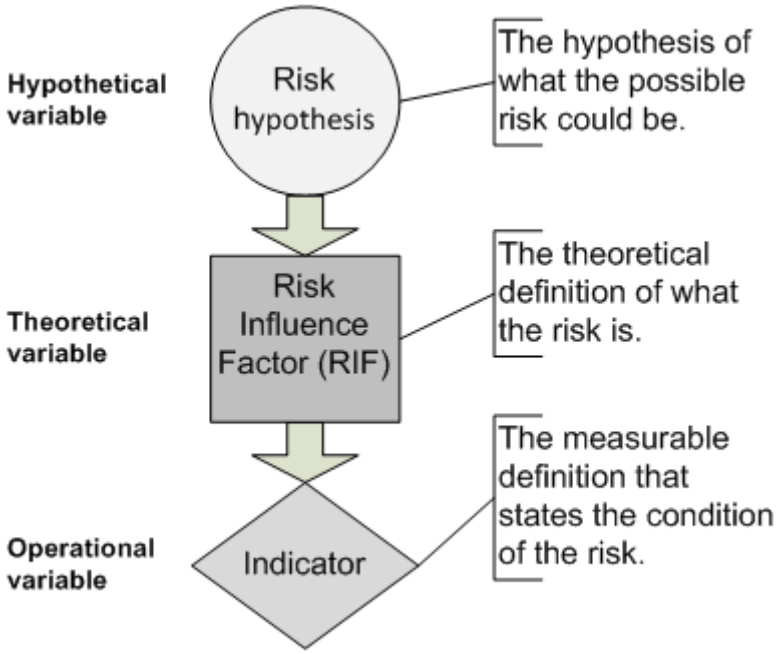

Figure 3.2: A measurement model, used to describe the three steps of developing indicators [15].

The first step in the development of indicators is about developing a hypothesis on the identified risk indicator, which the process for can be seen in Figure 3.2. The hypothesis is supposed to give an understanding for what the risk influence involved with the threat and effect could be. Based on that, the hypothesis for the two groups of inputs is going to state the risk influence of a fire event, whether it be the threat exposure or the effects on the business. The threat would likely be set in relation to the fire triangle or activities that combines them and the impact is set in relation to what values a building can possess to a business.

The second step is where the risk indicator becomes theoretical. This means that the hypothesis stated in the previous step is analysed to establish RIFs such that the risk of the indication can be defined. This step would often take into account historical data to prove the reliability of the RIFs or otherwise other substantial evidence that points to the same.

The third and last step is where the theoretical term stated in the previous step has to become operational. This means that when the inputs have been established to state the risk influence on a building, involved with the individual threat or effect, the next thing would be to make it measurable by using statistical data such that it can be used as an indicator.

The measurable instrument developed for the threat and effect is supposed to give a hint on the risk influence involved when having this indicator or quantum of the same present. With the measurable variable defined it makes it possible to evaluate the risk of a given building, by the application of this measurement.

3.3 The identification of indicators

The identification process of finding threats and effects to be used for the development of indicators, has been accounted to be one of the more important steps in the pursuit for useful indicators. The fundamental reason for this importance is due to the fact that unidentified threats and effects are unidentified risks. That is even though it might not be possible to develop useful indicators on all the identified threat and effects, due to the diversity of the inputs or their application in a final risk level scoring.

The identification of hazards or threats is one of the more important steps in the risk assessment process and it is therefore important that this step is carried out with great creativity to reveal as many threats as possible [34]. This is due to that it might be possible to come up with the majority of the threats in a limited time, because one might have been familiarized with the subject or based on experience [34]. For that reason, different research methods have been applied to uncover as many possible hazards and threats that can be uncovered. The methods applied are based on uncovering threats that are known to the project group, experts and those implicitly or explicitly known, which is why the applied methods shown in Figure 3.3 are the ones used for identifying these threats.

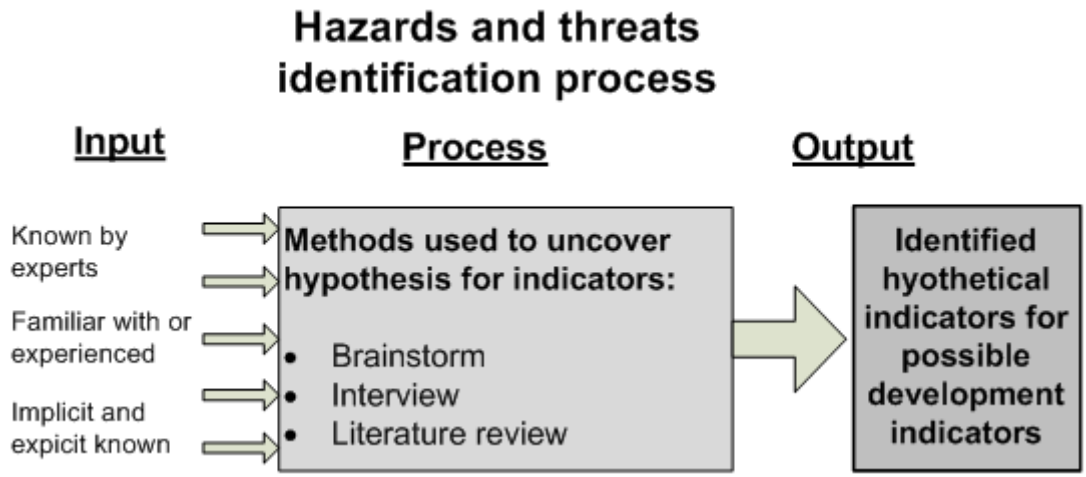

Figure 3.3: The identification process is carried out to obtain knowledge of possible parameters for indicators development, with the application of the three methods seen in the figure.

The process of revealing parameters to be used in the pursuit for developing possible indicators is carried out by the use of interviews, literature study and brainstorms. Brainstorms create the basic foundation for what paths are going to be explored. This application allows the process to be creative, especially when the brainstorming process is carried out as a iterative process and is made again when the project has gained a substantial amount of new knowledge [35] and [36]. When brainstorm are made, the outcome and wonderings emerging from it are adapted to be used in the following interview or literature research.

3.3.1 Interviews

The interview process is based on a seven phase process seen in Figure 3.4. The application of this process is useful in guiding one through the interview phases and to ensure that the objectives set out in the beginning are achieved in the end. The iteration in this process can be seen in the figure, starting from the design of the interview and going down to the analysis of the outcome, which is due to that new knowledge is identified at this point. This makes it useful to go back into the design of the interview, to review if any changes could be made to uncover other hazards or threats to reveal as large a quantum as possible.

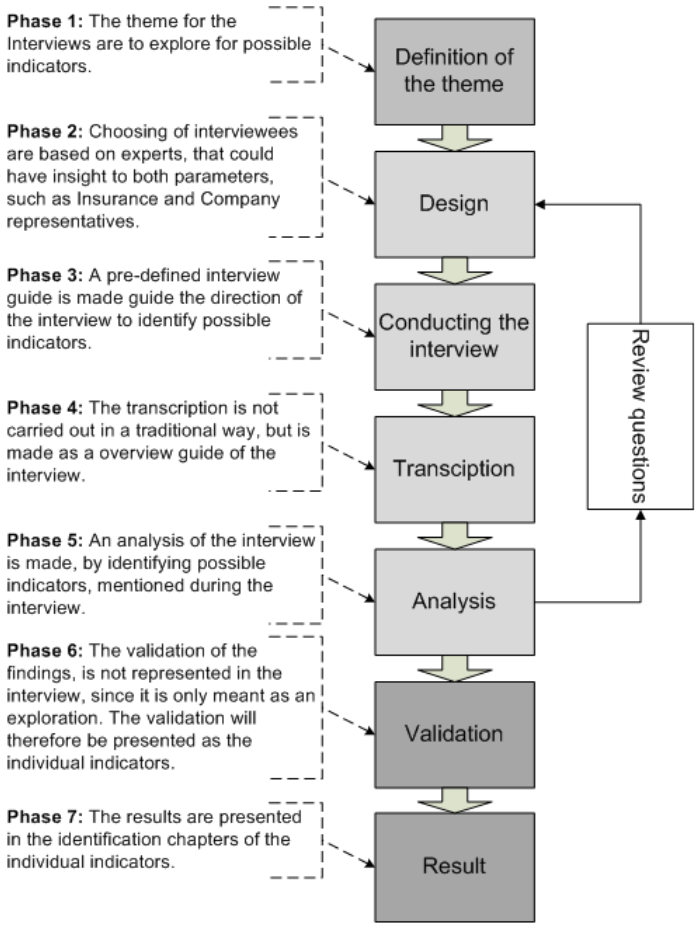

Figure 3.4: The seven phase process of conducting interviews [37].

In this seven step interview process there is one step that is the most important for identifying the threats and effects. The step that is referred to here is the design of interview phase and the reason for its importance is that it is during this phase that the means to achieve the objectives are defined, which include choosing types of interviewees and formulate questions for them. The objectives that the interviews are founded on can be seen below.

- Explore for implicit and explicit used parameters for FI.
- Explore for implicit and explicit used parameters for BII.

These objectives are the ones that guide the interview in the right direction and are not are part of the iteration to be changed as was shown in Figure 3.4. However, what is a part of

the iteration, is to choose new interviewees and prepare questions for them. This is due to the exploration of new threats and effects and that the goal is not to get all of the interviewees to agree on the same content since the limitation of interviews is that they are hard to make general statement from [38].

The whole interview process in steps can be found in Appendix C. In this appendix there is information about the interviewees that participated in the interviews and why they were chosen. The interviewees are also listed below where it is shown how they are referred throughout the project.

- Jesper Scott Johnsen (JSJ|Topdanmark: min:sek -00:00)
- Flemming Damholt (FD|Danish Crown A/S: min:sek -00:00)
- Ane Prehn Meyland (APM|Novo Nordisk A/S: min:sek -00:00)
- Lars Æbeløe-Knudsen (LÆK|Copenhagen University: min:sek -00:00)

3.3.2 Literature review

The literature review is used as an important part of the exploration for the two inputs. The reason for its importance is that when brainstorms and interviews have been carried out there is a need for a review of the literature that lies behind the assumption or discoveries made from the outputs of the interviews and brainstorms. It can be noted that the literature review is an essential part of the exploration for finding threats and effects that can lead to indicators.

During the project, the literature review serves the purpose as a supporting activity to reveal threats and effects and potential indicators in the sense that, information gained is reviewed in literature to find relations. As the project moves towards more specific information about the threats and effects the literature review becomes more specific in terms of what is reviewed and towards the end the review of literature is comprehensive in developing measurements for the indicators. It should therefore be understood that the literature review follows an iteration process, or a spiral as seen in Figure 3.5 where the more knowledge is gained the more specific the literature review gets [39].

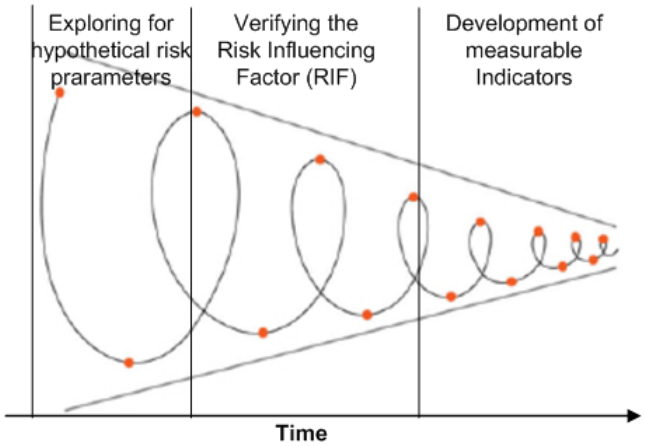

Figure 3.5: Iteration spiral for the literature review, represented from the beginning where research is very broad to the end where the research becomes more specific [40].

Chapter 4

Identification of indicators

This chapter will be concerned about describing what processes were used for identification of indicators and what indicators were found. The goal is to give the reader a basic understanding of the process used and the findings of using those processes.

4.1 The identification process

The identification process starts by creating a so called basic foundation. This foundation consists of an brainstorming process in order to gather information about what is known about indicators and what is not known. The goal of a brainstorming process is to think of all possibilities that come to mind and not to exclude anything as a possibility even though it might not sound correct. This is done in order to cover as large of a part of the knowledge as possible and by saying that no idea is a stupid idea helps the creative process of brainstorming by keeping the minds of the participants open.

The brainstorming was a two part session where the first part is where the fire indicators where brainstormed on and in the second part the business impact indicator were brainstormed on. When doing an brainstorm it is important to have a goal in mind or a theme on what you are brainstorming on and in these cases a theme was used as can be seen in the list below:

1. What can the fire threats to a building be?

   The brainstorm for the fire indicators evolves around finding out what the fire threats to a building can be.

2. What effect can a fire in a building have?

   The brainstorm for the business impact indicators evolves around finding out what effect a fire can have on a business.

One of the focuses for this project is that the indicators are supposed to be useful when being used from an office which means that they have to reflect threats and effects that can be found information on without physically inspecting the building. That means that it is focused on general building parameters that information can be acquired fairly easily and without the need of an inspection

The focus of the projects and the brainstorming criteria led to the discovery of the Building and Residential Registry (Bygnings- og boligregistreret BBR) where multiple building parameters for every building in Denmark can be found [41]. This fulfils the focus of being able to get the information without inspecting a building and builds a basic foundation for the next steps in the identification which are interviews and literature review. For a full list of all the parameters that have to be registered in the BBR registry, see Appendix D.

The brainstorming created the basic foundation for the identification of indicators and for further identification of indicators, interviews were carried out. The interviews are used to probe the practical knowledge of people that have substantial knowledge in the fields of fire, insurance and business. The findings of the brainstorming are used as an input in to the interviews to try to drag out any information possible out of the interviewees.

The interviews can give some knowledge that was not thought of in the brainstorming process and provide an insight into the industry the particular interviewee is involved with, that is not possible for outsiders to know. The goal of the interviews is not to create a consensus around the particular indicators that have been found prior to the interviews or to seek validation that they are indicators but to purely probe the knowledge of the interviewees to help identify indicators that might have been overseen in the brainstorming.

After creating the basic foundation with the brainstorming and expanding on that foundation with the interviews with industry experts, a literature research was carried out as the last step in the identification process. The literature research is carried out to verify the information from the brainstorming and interviews to see if the information from there can be backed up by literature. The literature research is also used to find data or information about the indicators that have been identified previously.

The processes that have been described here as the brainstorming, interviews and literature research are an iterative process that continues through the identification of the indicators. This process starts with the brainstorming to see what information is known, this information is then expanded with interviews and the purpose to identify more or other indicators that have not been brainstormed. The results from the brainstorming and interviews determine what needs to be looked into further in the literature review. These iterations are carried out as long as the identification period lasts and the process is repeated for each interview that is carried out.

In the next section the identified fire indicators will be presented and in section 4.3 the business impact indicators will be presented.

4.2 Identification of fire indicators

In the previous section the processes for identifying the fire indicators was described. However no criteria was set forth as to what the indicators have fulfil other than that they have to show general building information that can information can be accessed about without conducting an inspection of the building. In the list below, further criteria for the identification of the fire indicators is set forth:

1. Susceptible

   This criteria means that it will make the building more susceptible to fires. Meaning that the building is more vulnerable to fires if the indicator fulfils this criteria.

2. Contribution

   This criteria means that it will contribute to the fire and possibly aid the fire spread in the building. This refers to possible fuel sources for fires that can contribute to the fire, making it worse.

3. Evolving

   This criteria means that it might make the fire evolve in a way to make it worse. Similar to the contribution but refers to a more volatile change in the fire.

4. Hazard

   This criteria means that it might be a fire hazard, meaning that it either has the potential to start fires as an ignition source, be fuel for fire or both.

5. Activities

   This criteria means that work or activities might lead to the ignition of an fire or escalate the fire spread of fire that has already started.

6. Process

   This criteria means that a process might lead to the ignition of a fire or aid in the fire spread of the fire.

In order to be defined as an indicator the indicator has to fulfil one or more of the criteria set forth in the list above. This leads to the actual identification of the fire indicators and where they could be identified.

As described in Section 4.1 three identification processes were used to identify fire indicators, brainstorming, interviews and literature research. These identification processes revealed several ways where indicators can be found and these are:

- The BBR registry

  The BBR registry contains general information about all buildings in Denmark. The parameters that have to be registered are therefore easily available and some of the parameters that have to be registered might fulfil some of the criteria set forth earlier. [41]

- Usage of statistical data

  The use of historical data contains information about fire events that have happened in the past and might offer up some indicators of fires by researching into. Here, one database has been found to be the most relevant or the municipal fire and Rescue service database (Redningsberedskabets Statistikbank (BRS)). It contains data on miscellaneous fire parameters that might fulfil the criteria set forth [43]. For more detail about this database see Appendix B

- Expert knowledge

  The use of expert knowledge is used in the form of interviews to get the interviewees to give their expert knowledge on what they think fire indicators could be.

- Other research

  The use of other research includes discussions with supervisors, research into published literature and brainstorming and can give some general knowledge of what indicators might fulfil the criteria set forth.

Having described the criteria that the indicators have to fulfil to be considered an indicator and described the ways they can be identified as well as where they might be found, a list of indicators has been developed. This list can be seen in Table 4.1.

Indicator	**What criteria does it fulfil?**	**Where was it found?**
What kind of work leads to fires?	Activities	Interviews
Outer wall material	Susceptible,Contribution, Evolving	BBR registry
What makes a company a risky business?	Susceptible, Contribution, Evolving	Other research
Are there open flames in the building?	Hazard	Other research
Electrical equipment	Hazard	Interviews
Heating/heating medium	Hazard, Contribution, Evolving	BBR registry
Roof material	Susceptible, Contribution, Evolving	BBR registry
Is there work 24/7?	Activities	Other research
Electrical installations	Hazard	BRS database
Household equipment	Hazard	BRS database
Usage of the building	Susceptible, Contribution, Evolving	BRS database
Size of the building	Susceptible, Contribution	Other research
Risky rooms	Susceptible, Hazard, Contribution	BRS database
Location	Activities, Susceptible	Other research
Number of floors	Susceptible, Contribution, Evolving	Other research
Installations that use gas	Hazard, Contribution, Evolving	Interviews
Flammable storage	Hazard, Contribution, Evolving	Interviews
Weather factors	Hazard	Other research
Production equipment	Hazard, Evolving, Contribution	Other research
Flammable chemicals/liquids	Hazard, Contribution, Evolving	Interviews
Vandalism	Hazard, Contribution, Evolving	BRS database

Table 4.1: The 21 fire indicators that have been identified with the criteria they match and where they were found.

All in all there have been identified 21 fire indicators that fit any of the criteria set forth earlier in this section. Table 4.1 shows the identified indicators, what criteria each one fulfils and where said indicator has been found. Some of these indicators will be analysed further in Chapter 5. There were identified more than the 21 indicators that were presented in the table. A total of 48 indicators that relate somehow to fire were identified but can not be directly classified as fire indicators but refer to safety measures, organizational factors, human factors and other factors that are not easily defined. 21 of these 48 have been presented here and the rest of the indicators, with explanations and information about them can be found in Appendix A.

4.3 Identification of business impact indicators

When it comes to identifying business impact indicators it becomes clear that businesses evaluate their values that can be lost, as monetary. This means that any business is concentrated on sustaining or increasing the cash flow that runs though the business because without it the business might not survive. This leads to that the criteria for the business impact indicators should be that they indicate a loss in monetary values.

The identification of the business impact indicators mainly comes from three areas. These areas are identified in Figure 4.1. Two of those require a literature research and one relies on expert experience and knowledge.

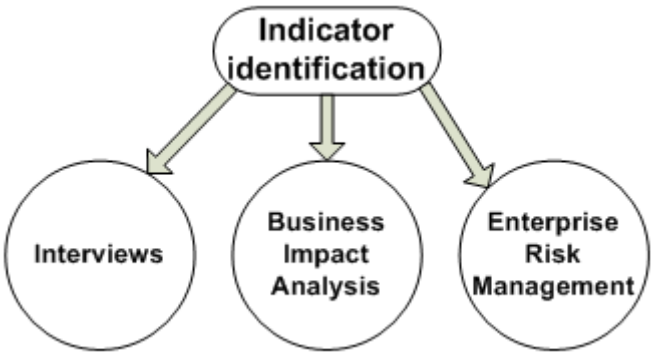

Figure 4.1: The three areas from where identified business impact indicators come from.

The three areas from the figure will be carried out individually in the following sections, with the purpose of presenting the identified indicators for each of the three areas.

4.3.1 Business impact analysis

The Business Impact Analysis (BIA) is an impact assessment approach applied in disaster management and IT management. The BIA analysis is a part of evaluating a business's continuity, from when a major event has occurred to it. The assessment is mostly based on subjective evaluation, which helps identifying the business most vulnerable assets that could be affected.

The primary idea with the BIA is to evaluate the business functions in order to identify the most critical functions of the business. The functions are evaluated on how relied the business is on them and how long the business could go without these functions. This emphasizes a similarity with the Porters Value Chain, where different activities of a business add to the businesses ability of creating values. The indicators from this approach that are carried out in a business are important for its future work.

4.3.2 Enterprise risk management

Another way to look at the business impact is by looking at Enterprise Risk Management (ERM) practices. The ERM is an approach that seeks to handle the whole enterprises risks. Next is a list of five areas that are considered a part of ERM practices.

1. Financial

   The impact on a business financial state is an impact on the cash flow of the business and thereby states the financial position of the business. This situation can for example be as a result of changes in the financial market, commodity prices and access to capital [44] and [45]. If there is an impact on the financial position for a business it leads to a change in the financial condition for the business with a short- and/or long-term effect.

2. Strategic

   Business strategies are the goals that are set forth to be achieved in the future. These strategic goals could be about the position towards competitors or the value created by the business [45], [46] and [44]. Strategic goals are the long-term effect that are aimed for, where means to achieve them are carried out in short-term goals. Therefore if the building serves as a mean to achieve the strategic goals, it could impact the business future, if lost.

3. Operational

   Businesses have a set of operations that they carry out in order to keep the business running. An impact on the operations is accounted as a business interruption and can lead to a decrease in the values produced. Depending on the type of value and operation, it can have an effect on the consumer, product quality, trademark and more [45], [44] and [47].

4. Reputational

   The impacts on business reputation are one of the businesses main concerns and they have been evolving as an effect of increased use of social media, which leads to fast communication spread, globally. The impact to a business reputation affects the stakeholders perception of the business, which could lead to that the stakeholders could affect the products or services made by the business [48].

5. Regulatory

   The regulatory risks are the ones that are bounded by laws and regulations to the business and its operations. An impact to a business could lead to a failure to comply with the laws, which could affect the future for the business. An event with a large societal effect could lead to legislative repercussions to the operations of the business [47] and [45]. As an example, the Seveso Directive which regulates the work with dangerous substances, emerged from an accident in the Italian town called Seveso [49].

With these five areas, the impact could be measured, for example, how the individual buildings are considered valuable for the business to achieve its strategic goals. From which the impact would be stated on what value the strategic goal was to generate for the business, which would be lost.

4.3.3 Interviews

From the interviews, it was discovered that the functions that are carried out in the individual buildings are an important factor to take into account when determining the impact it could have on the business. The main focus was on the following four functions:

- Production

  If lost, the impact would be on the loss of products which could be a large monetary loss for the business (APM|Novo Nordisk A/S:01:00-03:20).

- Research and Development (R&D)

  The R&D is an important function for the business to keep its competitive advantage (APM|Novo Nordisk A/S:08:40–09:15). The closer the product is to being launched to market the bigger the impact would be (APM|Novo Nordisk A/S: 10:10–15:55).

- Offices

  Offices are of less importance due to the fact that they are easily replaceable or that people would just be able to work from home. It is therefore only considered as lost property.

- Storage

  The storage of product for the business is also of insignificant importance, but only if the production can be sped up to keep up with the demand for the products.

Furthermore, it was identified from the insurance point of view that there is a difference between the value of the building (JSJ|Topdanmark:31:16–33:38) and the value of the lost production (APM|Novo Nordisk A/S:01:00-03:20). Out of those two, the respondents state that production loss has the biggest impact on the business from losing a building (APM|Novo Nordisk A/S:01:00-03:20). It was also identified that other impacts than direct monetary loss could be on the business reputation (APM|Novo Nordisk A/S:27:55–32:25) and loss of market to competitors (JSJ|Topdanmark:33:38–38:34).

One of the final discoveries from the interviews was that businesses are also concerned about the impact from a compliance failure. For example, for Novo Nordisk it is crucial that quality documentation on sold products is in order. A failure to comply with these could lead to a product recall, which could also affect the reputation (APM|Novo Nordisk A/S: 10:10–15:55).

4.3.4 Identification of business impact indicators summary

From the research that was conducted, a pattern started to emerge where the business impact of monetary values were divided in to two categories with regards to how they are measured. These two categories are direct indicators and indirect indicators which are explained in Figure 4.2.

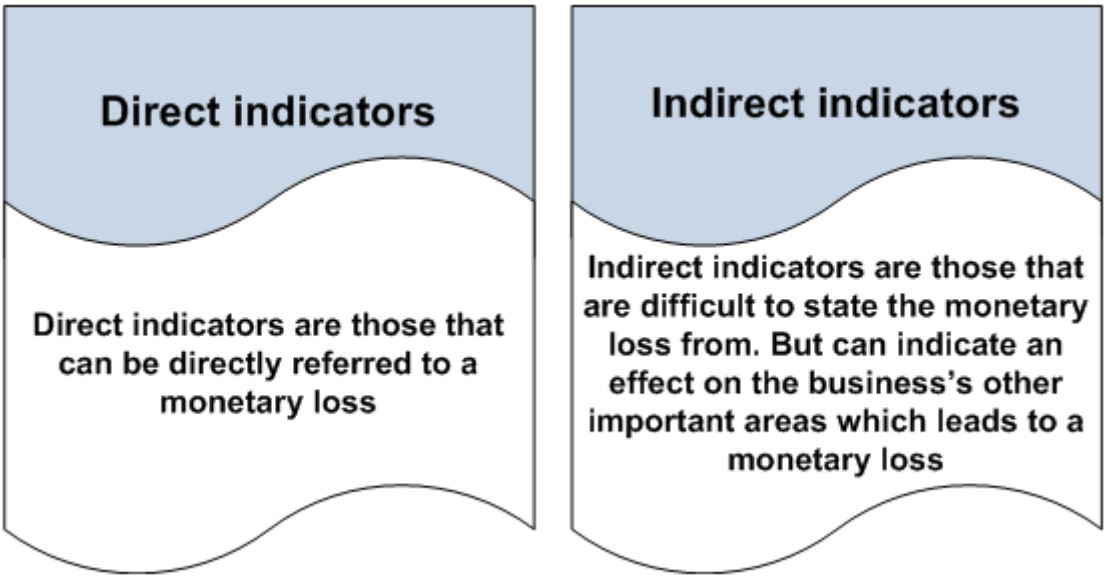

Figure 4.2: The difference between direct and indirect indicators.

4.3.5 The direct and indirect business impact indicators

Table 4.2 lists the different impact indicators that were identified to be potential indicators to measure the impact from a fire event of a building.

Business impact indicators	Hypothesis	Where found?
Direct		
Physical loss	The loss of materials and equipment represent a part of the economical loss.	Interview
Business Interruption	The loss in production, leads to loss in future earnings and is considered the biggest impact to the business from losing a building.	Interview
Indirect		
Compliance	Failure to comply, can affect the business to get the product out to the customer, but can also affect the reputation.	Interview
Reputation	Reputational loss, can lead to customers changing products, or loss in market value.	ERM, Interview
Financial	Can asses the business financial capabilities.	ERM
Strategic	Can indicate if the business cannot achieve their future goals.	ERM
Regulatory	Can indicate if further restriction would be made, or compliance is lost.	ERM
Operation	Can indicate the daily losses in created value.	ERM
Business function	The functions importance to the business that is carried out.	BIA, Interview

Table 4.2: A list of identified and hypothesized business impact indicators.

Chapter 5

Development of fire indicators

In this chapter an analysis of the fire indicators that were presented in Chapter 4 will be made where the hypothesis for each parameter will be set forth. Furthermore, the risk influence factors for each indicator will be presented as well as connecting the risk influence factors to literature.

5.1 Indicator selection

In Table 4.1, 21 fire indicators were identified. Analysing 21 indicators would be quite a task and as such it was decided to prioritize some indicators before others in order to limit the amount of analysis that has to be done. The prioritization or selection of indicators to keep was made by putting forth criteria that the indicators have to meet.

As it is the intention to develop measurements for the indicators and use them in a preliminary risk evaluation in the end, an important criteria is that information about the indicators is easily available and that data can be collected which can be used to determine occurrence and relevance of the indicators. The indicators that met these criteria are set forth in the list below:

- Location

  The location is selected because it can show different risk levels based on where in Denmark the building is located and thus give a good input into the risk evaluation and aid in the prioritization of buildings based on their location.

- Risky rooms

  The rooms of a building are selected because they should be able to give a clear picture of the risks involved in the building and help with prioritization of buildings based on what kind of risky rooms they have.

- Size of the building

  The size of the building is selected because it can be used to indicate the expected number of fires that the building could have based on its size and the usage of the building.

- Usage of the building

The usage is selected because the usage of a building can tell about the amount of potential ignition sources in the building which can give an indication vulnerability towards fires.

- Building materials

  The building materials are split up to outer wall materials and roof materials and are selected because if they are made out of combustible or flammable materials they can give an indication of fires.

These indicators are either required to be registered in the BBR registry or can be found in the BRS database which makes them suitable candidates for being analysed, as will be done in section 5.3, one by one [41] [43]. The analysis of each indicator will start by introducing the hypothesis for it, moving on to discuss the risk influence factors it influences and showing how statistical data can be used to develop the indicators.

There are two other indicators that are also included in this chapter, the number of floors in a building and F-gas installations. These indicators are included to show how indicators can be developed without the use of statistical data and consequence measures. Because these indicators are not developed from data they will be less valid with regards to their risk scores as they will be developed subjectively rather than objectively and are thus not as concrete as the other indicators. these are the last two indicators in this chapter and are in sections 5.4.1 and 5.4.2.

The indicators that have been described in the text above can be split up in to two categories based on how they are realized. Firstly, there are the indicators that can be made using statistics, historical data and literature and secondly, those who can be made by using reasoning, literature, arguments and general knowledge. They are further described in the following text:

- Primary indicators

  These indicators are those who can be made using statistical data, historical data, literature and general knowledge to prove that the indicators due actually indicate something. The indicators in this category can be developed such that they can be measured on and developed risk scores for, using statistical or historical data.

- Secondary indicators

  These indicators are those who can only be made using reasoning, literature, arguments and general knowledge to show that these indicators can indicate towards fires. However, it is not possible to develop either measurements or risk scores on these indicators using statistical or historical data but can be done in a subjective way instead and can still be used as an indicator but it just won't be as reliable as the primary indicators.

In the next section the data that is used for the primary indicators will be presented as to where it comes from, how it can be used and what the possible flaws with the data can be.

5.2 Information about the data

The data for the primary indicators is gathered from the statistical database operated by the Danish Emergency Management Agency (Beredskapsstyrelsen (DEMA)) which is called the Municipal fire and rescue services database [43]. The data can be split up into categories

after what type of places they occurred in. There are 12 different placement categories and five of those are relevant to this project since the scope is to cover public and non-residential buildings. The placement categories that cover the scope of public and non-residential buildings can be seen in Figure 5.1.

Figure 5.1: The five placement categories and what types of businesses and public services are included in each category [43].

From the figure it is possible to see what types of public services and business are included in each category. Knowing this allows us to better understand the data and help with analysing the data for the different indicators.

The database offers data from fire departments from all over Denmark and the data ranges from 2007 until 2015. The registration of events for 2015 in not finished and is therefore excluded from this project. The database offers a simple and an easy way to gather data for possible indicators for development. The database gives the potential to use data and/or statistical trends as indicators for Denmark.

The data in the database has to be taken with a notice as it could be called a somewhat gray area. This is because the data is input by the local fire departments throughout Denmark and the definitions for fire sizes, causes, location and such might differ in the way they are input from fire department to fire department. Also, the way some of the data has been

classified within the database has changed for some input parameters throughout the years where it has been input under a term that has a wide meaning but in recent years has been broken down to some more specific terms.

Another gray area is the data itself. The data within the database is not 100% split up into its multiple possible categories of causes, objects, fire placements and such as there are categories within these that are called unknown and other. This means that if the cause of fire is not known, or the room where the fire starts is not known it is possible for the person who is inputting the data to register it as either unknown or other. The amount of fires that are registered as unknown or other differs between which fire category is being looked at but as an example in the category for suspected causes of fires there are a total of 10.033 fires and of those, 4.573 fires are registered as unknown or other. This means that about 45% of the fires in that category do not have an assigned cause to them which might give a little skewed picture of what the most likely causes for a fire are [43].

The data only covers the fires in Denmark where the local fire department has responded to it and thus does not include a full picture of how the fires are in Denmark. This can be seen in Figure 5.2

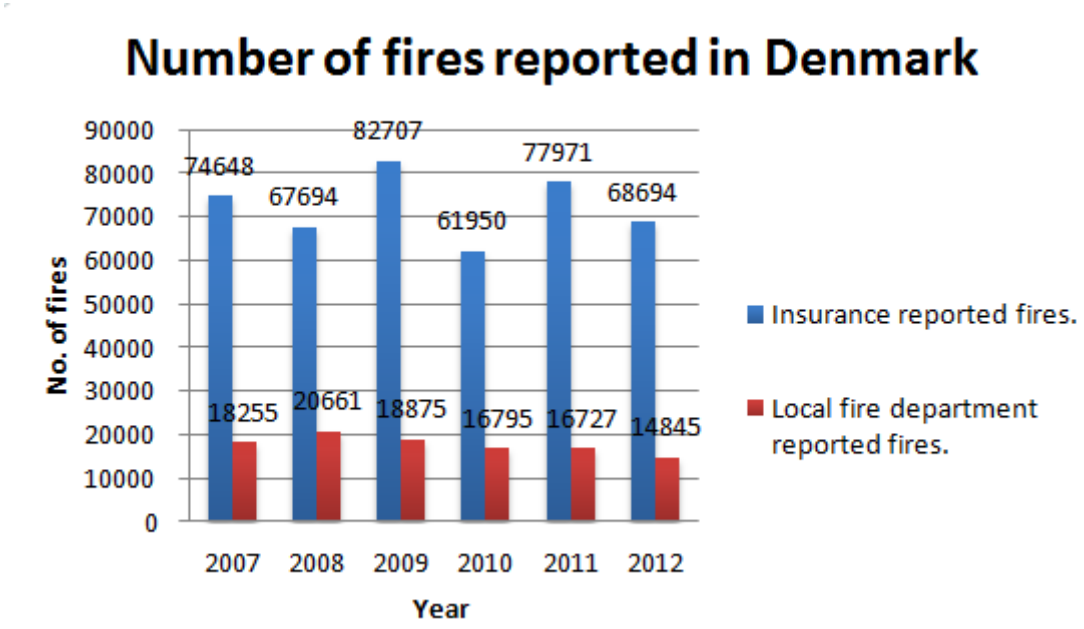

Figure 5.2: The graph shows the distribution of fires in Denmark from 2007-2012. Approximately 24% of the fires are reported and responded to, by the local fire department [50].

This is due to that approximately 76% of fires involving a building or its inside materials are only reported to insurance companies and do not involve the local fire department [50].

It could be read from this that the fires that are reported to the local fire department tend to be of a bigger nature than those that only get reported to the insurance companies as the involvement of the fire department is not needed. For more information about the database and what information it contains see Appendix B.

In the next section the primary and secondary fire indicators are developed.

5.3 Primary fire indicators

In this section the five primary fire indicators that have been selected will be analysed based on their risk influence factors and how those can be related to the risk level of a building. The indicators will be broken down and shown how they could be developed into fire indicators using statistical data.

5.3.1 Location

The hypothesis for this indicator is that location can be the cause of fires and pose a risk towards a building. A building can be affected by its location as to how the surrounding environment is as well as how the weather can differentiate between locations. In the BRS database there are listed 18 possible causes of fires and of those 18, two can be related to location, weather and arson. These risk influence factors can be seen in Figure 5.3 [21].

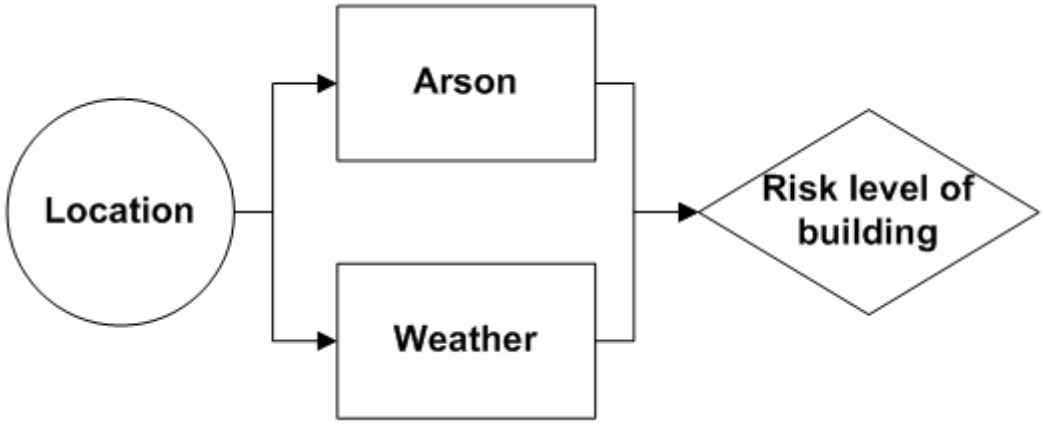

Figure 5.3: The risk influence factors of the location and how they influence the risk level of the building.

Using these risk influence factors, data was collected from the BRS database to see how and if location can be used as an indicator with arson and weather as the risk influence factors. The data in the database can be split up by location and the locations refers to the five regions of Denmark, the Capital area, Zealand, Central Jutland, North Jutland and Southern Denmark. These regions are used for this indicator to see if there is a difference of fire risk between the regions. The goal with this indicator is to be able to see how the risk changes for each of the five regions within Denmark and as well how the risk changes between industries within the five regions. Such that an industry in the Capital area might differ from the same industry in Zealand for example.

Subsequently, the total number of fires for each region is found. However, since the scope of the project does not involve residential buildings, five industry categories are used, as was described in Section 5.2. Next it will be shown how this indicators was developed. The first step is to find the total number of fires for each of the five industries in Denmark which can be seen in Table 5.1.

Industry	No. Fires	Symbol
Primary businesses	2.451	N_1
Secondary businesses	2.216	N_2
Tertiary businesses excl school fires	4.034	N_3
Tertiary businesses school fires	719	N_4
Other businesses	613	N_5
Total	**10.033**	**N**

Table 5.1: The number of fires for all fire locations and the total number of fires [43].

The next step is to take our risk influence factors, arson and weather, and see how many fires they have been the direct cause for, for each of the five industries. This can be seen in Table 5.2.

Industry	No. Fires	Symbol
Primary businesses	140	n_1
Secondary businesses	72	n_2
Tertiary businesses excl school fires	468	n_3
Tertiary businesses school fires	202	n_4
Other businesses	113	n_5
Total	**995**	n_{total}

Table 5.2: The number of fires caused by arson and weather for all of the fire locations [43].

The total number of fires that are directly caused by either arson or weather is 995 and since this number only tells the total number of fires directly caused by either arson or weather, a connection to the five regions in needed. This connection can be seen in Table 5.3.

Region	No. Fires	Symbol
The Capital area	291	r_1
Zealand	237	r_2
Central Jutland	173	r_3
North Jutland	71	r_4
Southern Denmark	223	r_5
Total	**995**	r_{total}

Table 5.3: The distribution of fires caused by either arson or weather for the five regions of Denmark [43].

The table shows how the 995 fires directly caused by either arson or weather are distributed over the five regions of Denmark. However, since the goal was to be able to see how the risk is distributed over different industries in different regions, a deeper look into the regions is needed to fulfil that. In order to do that, an example will be shown for the Capital area region. From Table 5.3 it can be seen that in the capital area region there are 291 fires directly caused by either arson or weather and a closer look at how those 291 fires are distributed over the five industries for the Capital area is needed. This can be seen in Table 5.4

Industry	No. Fires	Symbol
Primary businesses	7	i_1
Secondary businesses	20	i_2
Tertiary businesses excl school fires	156	i_3
Tertiary businesses school fires	79	i_4
Other businesses	29	i_5
Total	**291**	i_{total}

Table 5.4: The number of fires caused by arson and weather for each of the five industries within the Capital area region [43].

With the information presented in Tables 5.1 - 5.4 and the intention of being able to differentiate between industries over the five regions, Equation 5.1 was derived.

$$\frac{n_{total}}{N} \cdot \frac{r_{1-5}}{n_{total}} \cdot \frac{i_{1-5}}{r_{1-5}} = Distribution\ of\ fires\ for\ the\ industries\ in\ a\ region \tag{5.1}$$

The first term in the equation gives the distribution of how many fires caused by arson and weather are, out of the total amount of fires for the five industries. The second term gives the distribution of how many fires for each region, caused by arson and weather are out of the total number of fires caused by arson and weather. The third and final term gives the distribution of how many fires are in each industry with regards to the distribution of how many fires for each region are caused by weather and arson. An example of the distribution of fires for the primary industry within the capital area is shown in Equation 5.2.

$$\frac{n_{total}}{N} \cdot \frac{r_1}{n_{total}} \cdot \frac{i_1}{r_1} = \frac{995}{10.033} \cdot \frac{291}{995} \cdot \frac{7}{291} = 0.000698 \tag{5.2}$$

Table 5.5 shows the rest of the results for each of the industries within the five regions of Denmark calculated with Equation 5.2.

Industry	The Capital area	Zealand	Central Jutland	North Jutland	Southern Denmark
Primary Businesses	0.000698	0.00379	0.00179	0.00379	0.00389
Secondary Businesses	0.00189	0.00179	0.00059	0.00099	0.00169
Tertiary excl school fires	0.01555	0.01086	0.00319	0.00728	0.00927
Tertiary school fires	0.00777	0.00429	0.00079	0.00299	0.00399
Other businesses	0.00289	0.00279	0.00059	0.00179	0.00299

Table 5.5: The results for each industry for all of the five regions in Denmark.

It has to be noted that the numbers used for the location indicator are taken from the suspected causes in the BRS database. It was described in Section 5.2 that out of the total 10.033 fires there are 4.573 fires that do not have a registered cause and are registered as unknown or other. This means that for this category about 45% of the registered fires, there is no cause registered. This shows that there is a great deviation in the data and that this indicator might give completely different results if all this data were available.

That being said it can still be said that the location of a building can influence how vulnerable it is to arson and weather and it differs from region to region and can therefore be said to indicate different risk for different regions and therefore can be used as an fire

indicator. However, as can be seen in Table 5.5 that the results are very small and that is due to that arson and weather do not account for many fires. This means that this indicators is possibly not the best one, but it will still help with distinguishing between buildings but just with a smaller contribution than other fire indicators and also depends on how big the risk for this indicator will be as the risk score might show a different result.

5.3.2 Risky rooms

The hypothesis for this indicator is that some rooms in a building pose a larger risk then other due the objects and/or the usage/activities being carried out in the room. This means that if a building possesses some of the rooms that pose a larger risk than others, it can be said to pose a higher risk for fires. This is also mentioned by G.Ramachandran, that "Frequency of fires also varies from one part of a building to another" in [51].

The risk influence factors for this indicator are related to the hypothesis and are set forth as the objects in the rooms or the usage or activities being carried out in said room. The risk influence factors for a room are:

- The usage of room
- The work/activities carried out in the room
- Objects in the room

Figure 5.4 shows the risk influence factors of the rooms and how they influence the risk in a room. The usage of a room determines the work or activities that will be carried out in the room which in turn determines what objects might be in the room.

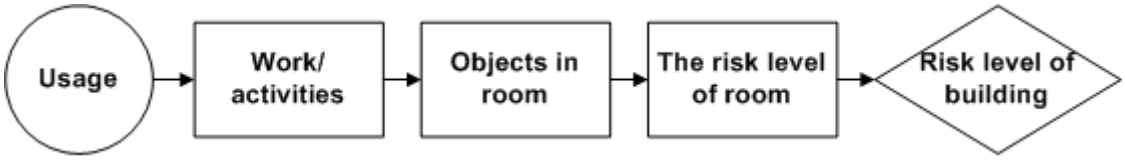

Figure 5.4: The risk influence factors of a room and how they influence the risk of a room.

For example if the usage of the room is a kitchen, that determines the work that can be carried in the room which in turn determines what types of objects are needed in the room. For a kitchen this could be anything from a toaster to gas stoves which in turn determine the risk level of the room. Continuing with the example of the kitchen it can be seen from the BRS database that since 2007, 978 fires out of a total of 10.033 building fires, roughly 10%, have been started in a room that has the designated usage as a kitchen [52]. This is most likely to the activities/work being carried out in the room as well as the objects being used.

Room	Primary	Secondary	Tertiary	School fires	Other
Assembly room	4	6	171	57	7
Barn	802	18	20	0	8
Bathroom	2	13	159	52	9
Bedroom	5	0	212	7	1
Boiler room	304	106	38	12	15
Chimney	68	24	15	0	3
Cleaning room	2	3	20	8	3
Elevator	1	3	8	0	0
Entrance	7	12	86	32	13
Garbage room	1	23	28	12	6
Hallway area	2	9	90	27	11
Hobby room	14	1	11	15	2
Kitchen	20	71	802	49	36
Laboratory	2	24	7	13	7
Common area	61	21	662	78	29
Machine house	227	87	23	6	6
Office	5	37	76	15	34
Sales area	0	24	172	0	24
Sauna	0	1	17	1	0
Scullery	2	2	3	0	2
Silo	47	171	26	4	9
Spray booth	0	55	5	0	10
Stable	465	4	2	0	1
Stairs	1	3	22	5	4
Stock room	59	360	286	9	78
Storage room	14	31	146	48	21
Storage, ceiling	17	11	34	7	2
Storage, cellar	0	6	30	9	6
Technical room	19	172	136	26	27
Underground parking	0	1	11	2	2
Waiting room	1	1	8	0	1
Wardrobe,locker rooms	0	5	23	5	3
Workshop	46	350	177	26	72
Total fires	**2198**	**1655**	**3526**	**525**	**452**

Table 5.6: The distribution of fires out of the total 10.033 fires for all the 33 rooms that are available in the BRS database [43].

Table 5.6 shows the distribution of fires for the 33 different rooms and how many fires have occurred in each room out of the total 10.033 fires registered in the BRS for the five placement locations that were selected in section 5.2 [52]. It can be seen from the table that if the total number of fires for each of the business industries are added together the total will be 8.356 fires but not the 10.033 fire mentioned before. This relates back to what was said about the unknown and other variables in the previous section. This means that 1.677 fires were not determined as to in what room the fires started in. That is about 17% of the fires that do not have an assigned room as to where the fire started and thus might give a slightly skewed picture of some or all of the rooms presented in this chapter.

Looking further into how the fires are distributed over the rooms for the different industries, Table 5.7 has been made. It shows four rooms and the distribution of fires for said rooms over the five industries. It can be seen that the distribution of fires vary greatly between the industries which implies that the rooms represent different levels of risks depending in which industry they are in.

Room type	Primary	Secondary	Tertiary	School fires	Other
Barn	**802**	18	20	0	8
Hobby Room	14	1	11	**15**	2
Kitchen	20	71	**802**	49	36
Silo	47	**171**	26	4	9

Table 5.7: The table shows how the fires are distributed for four rooms over the five industries. This shows that the industry type matters when selecting a room [43].

This shows us that it is important to differentiate the rooms based on what industry they are in as the risk can differ greatly between the same usage of a room depending on what industry it is in. Tables 5.6 and 5.7 show that the number of fires differentiate greatly between rooms and that the room type can be used as an indicator of a risk level of a room. The distribution of the fires also differs for the rooms between the placement in the business industries which is most likely due to the nature of the different business industries and what kind of activities go on under them. This shows that different types of rooms carry different fire risks in a building and can therefore be used as an indicator.

5.3.3 Usage of the building

The hypothesis for this indicator is that different usages of building pose different risks. The risk influence factors for this indicator are the usage of the building which in turn determines what the ignition sources are within the building which determines the risk level of the building as can be seen in Figure 5.5.

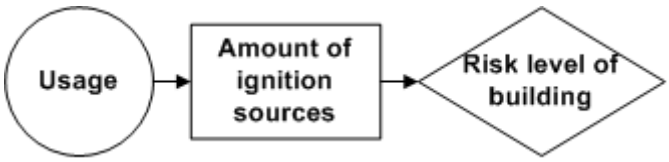

Figure 5.5: The risk influence factors of the usage of a building and how they influence the risk level of the usage category of the building.

The figure shows that the risk level of the usage depends on the risk influence factor of what the usage is, which in turn affects what type of ignition sources can be in the building as well as the amount of them. This is also stated by G.Ramachandran "The nature and amount of ignition sources and, hence, frequency of fires would vary from one type of industrial building to another and cause to cause within a type."[51].

To show this the same 16 categories are used as in Section 5.3.4 and the number of fires for each category are extracted from the BRS database. Then the distribution of fires for each category can be calculated to show how different usages have different distributions of

fires and hence that could be related to the risk of the building usage. This can be seen in Table 5.8.

Building usage	No. fires	% of total fires	Building usage	No. fires	% of total fires
1. Residential care with permanent stay	684	15.9	9. Unspecified transport and trade	-	0
2. Farming and operational	986	22.6	10. Libraries, churches, museums and etc	96	2.2
3. Factories, workshops and etc	671	15.7	11. Teaching, research and etc	278	6.5
4. Electricity, gas, water and heating plants	135	3.1	12. Hospitals etc	110	2.6
5. Other buildings for production	-	0	13.Day care centres	90	2.1
6. Transport or garage	126	2.9	14. Unspecified institutions	-	0
7. Offices, trade, warehouse, public admin and etc	343	8.0	15. Sports houses, clubhouses and etc	71	1.7
8.Hotels, restaurants, hairdressers and etc	220	5.1	16. Other	492	11.5

Table 5.8: The 16 different usage categories are shown with the number of fires for each category and the distribution for each category out of the total number of fires [53] [43].

There are three categories that are not calculated as no data about fires for those categories can be obtained. The table shows that the distribution of fires differs from usage category to usage category which means that there is a difference in the risk of what the building is being used for. This shows that the usage can be used as an fire indicator as different usages of buildings carry different risk levels associated with them.

5.3.4 Size of the building

The hypothesis for this indicator is that the larger a building is, the more likely it is to have fires. The usage of the building could also play a role as the usage of the building could influence the amount of ignition source as well. This is based on that the larger a building is the more ignition sources could be in the building and that the ignition sources might also depend on what the building is being used for, therefore the size of the building and the usage can be used to determine the risk level of it.

The risk influence factors for this indicator are related to the hypothesis and are set forth as the size of the building in m^2, the usage of the building and the amount of ignition source the building could have. This can be seen in Figure 5.6.

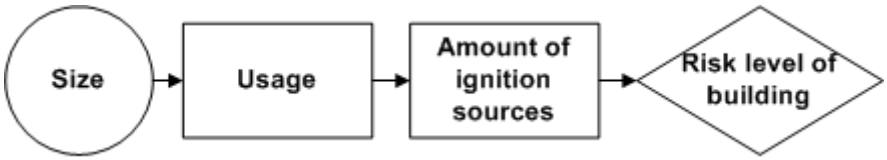

Figure 5.6: The risk influence factors of a building and how they influence the risk level of the building.

This is based on the work that G.Ramachandran has done, where he claims that "The probability of fire starting depends on the nature and amount of ignition sources present in the building. The latter increases with the size of the building and, hence, the probability is primarily a function of the size" [51]. From this it can be deduced that the size of a building could be used as a fire indicator as the probability of a fire occurring would increase with the size of the building if one assumes that the ignition source increase in number with the size and can give an indication of the risk level of the building.

The usage of the buildings has to be taken into account because if you are comparing two buildings that are the same size they would represent the same risk. However, one of those buildings could be an office building and the other a dynamite factory which carry vastly

different risk levels, having the dynamite factory being more riskier than the office building. Therefore the usage has to be taken into account with this fire indicator.

Danmarks Statistik (DST) is a website where miscellaneous data about trends in Denmark is collected and published [53]. Amongst those is the size of non-residential buildings within Denmark. This websites database was used to collect data about the different sizes of non-residential buildings in order to incorporate into an indicator. The data is split up into 16 usage categories of building usage, which are:

1. Residential care with permanent stay
2. Farming and operational
3. Factories, workshops, etc
4. Electricity, gas, water and heating plants
5. Other buildings for production
6. Transport or garage
7. Offices, trade, warehouse and public administration etc
8. Hotels, restaurants, hairdressers etc.
9. Unspecified transport and trade
10. Libraries, churches, museums etc.
11. Teaching, research etc.
12. Hospitals etc
13. Day care centres
14. Unspecified institution
15. Sports houses, clubhouses etc
16. Other

The data for the sizes of the buildings within these 16 categories cover the years from 2011-2014 as those are the only years the building sizes are available for. For showing how the size and the usage can be used as an indicator a single example will be provided. The example will involve one of the usage category previously presented. The usage category number three in the list above or the factories, workshops and etc. The sizes of the buildings within this category were extracted from the DST database and the number of fires from the BRS database and are presented in Table 5.9

Year	2011	2012	2013	2014	**Total**	**Average per year**
No. of m^2	53.937.000	54.000.000	53.965.000	53.823.000	**215.752.000**	**53.931.250**
No. of fires	178	179	169	145	**671**	**167.75**

Table 5.9: The table shows the total amount of square meters for each year in m^2 with the number of fires for each year, the average fires per year as well as the average square meters for a year [53] [43].

Table 5.10 shows the distribution of the fires that were presented in Table 5.9 and the different building usages that classify to be under the usage category of factories, workshops and etc. These number are extracted from the BRS database.

Category	No. of Fires
Production company	2
Clothing industry	9
Production of food and beverages	155
Iron- and metal industry	212
Chemical industry	48
Leather industry	4
Paper industry	35
Plastic industry	59
Textile industry	14
Tobacco fabrics	4
Wood and timber industry	129
Total	**671**

Table 5.10: The building types that are under the usage classification of factories, workshops and etc [43].

The average number of square meters per year and the average number of fires per year can be related to create a fire frequency calculation for this building usage category as is shown in Equation 5.3 which can be used to calculate the expected fires per year for a building in the usage category number three or the factories, workshops and etc, based on the size of the building.

$$\frac{Average\ number\ of\ fires\ per\ year}{Average\ number\ of\ Square\ meters\ per\ year} = \frac{167.75}{53.931.250} = 3.11016E-6 \tag{5.3}$$

The result from the equation is the frequency of fires for buildings in this building usage category and can be used do determine the number of expected fires for a building in this usage category by multiplying the size of the building with the result from Equation 5.3.

The same calculations have been done for the other 16 building usage categories as can be seen in Table 5.11. Three building usage categories do not have an frequency and that is due to that no information could be found for the number of fires in these categories in the BRS database.

Building usage	Frequency	Building usage	Frequency
1. Residential care with permanent stay	1.34E-4	9. Unspecified transport and trade	-
2. Farming and operational	1.79E-6	10. Libraries, churches, museums and etc	4.84E-6
3. Factories, workshops and etc	3.11E-6	11. Teaching, research and etc	3.12E-6
4. Electricity, gas, water and heating plants	9.27E-6	12. Hospitals etc	6.19E-6
5. Other buildings for production	-	13. Day care centres	6.43E-6
6. Transport or garage	5.06E-6	14. Unspecified institutions	-
7. Offices, trade, warehouse and public adm and etc	1.32E-6	15. Sports houses, clubhouses and etc	2.77E-6
8. Hotels, restaurants, hairdressers and etc	8.83E-6	16. Other	3.34E-6

Table 5.11: The building usage categories and the fire frequency of of each category have been calculated using Equation 5.3.

Looking at Table 5.11 it can be seen that there is a difference in the fire frequency depending on what building usage category is being used. The size can then be used as an input to be multiplied with the fire frequency of a given building usage category to give the expected number of fires per year. If a building is 50.000 m^2 and is in the usage category of

factories, workshops and etc then the expected number of fires per year can be calculated as seen in Equation 5.4.

$$Total\ m^2 \cdot Building\ usage\ category\ frequency = 50.000 \cdot 3.11E-6 = 0.1555\ fires\ per\ year \tag{5.4}$$

Even though the results of the equation say that the expected number of fires per year is 0.1555, a building this size and within this usage category will have a single expected fire roughly every 6 years. This shows that buildings within this usage category would get a different expected number of fire per year that can be said to relate to the risk level of the building. This means that this can be used as an indicator for fires and shows that there is a difference in the risk based on the usage and size of the building.

5.3.5 Building materials

This indicator refers to the materials that are used in the building. The hypothesis is that there are used many different materials for buildings that have different fire properties as to how long they can resist fires, their combustibility and that they can act as a fuel source by being flammable. Figure 5.7 shows the risk influence factors for the building materials type and how they can influence the combustibility and flammability which in turn can influence the potential spread of fires.

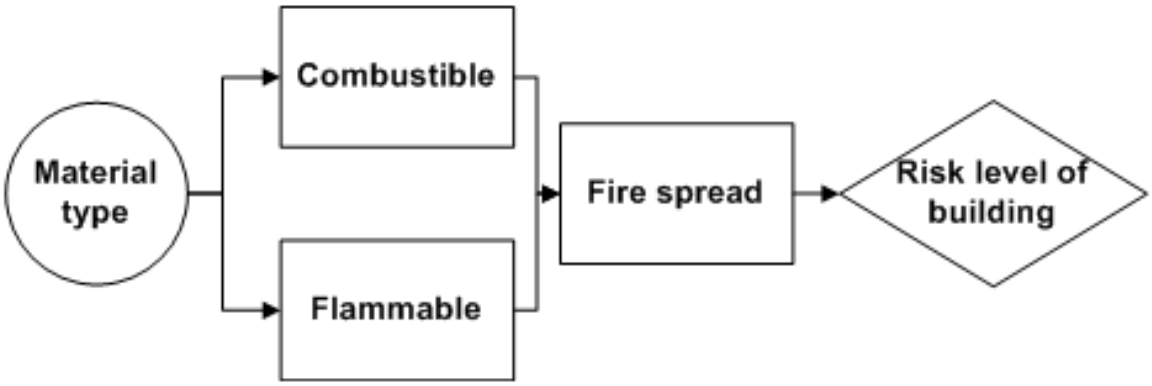

Figure 5.7: The influence factors of the material types and how the influence the risk level of the building.

There are extremely many different types of materials used in buildings and there is a need to delimit this indicator somewhat. Inspiration was sought to the European Standard EN 13501-1 which title is: Fire classification of construction products and building elements- Part-1: Classification using data from reaction to fire tests [54]. This standard is set forth by the European Committee for Standardization and covers the fire classification of all construction materials. The different classes and their meaning can be seen in Figure 5.8.

Classification according to European Standard EN 13501-1.

Definition	Description	Construction product	
Non combustible	No contribution	A1	A2
Combustible	Very limited contribution to fire	B	
Combustible	Limited in contribution to fire	C	
Combustible	Medium contribution to fire	D	
Combustible	Highly contribution to fire	E	
Combustible	Easily flammable	F	

Figure 5.8: The different fire classes from the EN 13501-1 standard [55].

There are seven classes and materials that are in classes A1-B are non-combustible materials or either contribute in a very limited way to a fire. Materials in classes C-D contribute to a fire in a limited to medium fashion and materials in classes E-F contribute to fires highly or are easily flammable. Some of the classification have further markings added onto them which are relevant for smoke generation and burning droplets which are not considered relevant for the combustibility or flammability of the products.

The classification can be interpreted as to materials in different classes pose different risks as shown in the list below:

- Classes A1-A2-B pose a low risk for flame spread
- Classes C-D pose a medium risk for flame spread
- Classes E-F pose a high risk for flame spread

Using these classifications, the materials can be split up into to two categories in order to simplify the classification of materials. This is to say that either a building has combustible materials or not. Such that if the buildings materials are in classes A1-B those are materials that are not combustible and the materials in classes C-F are combustible. A building which has non-combustible materials then has a lower risk of contributing to flame spread than if it had combustible materials. The materials that should be used with this indicator are the outer wall materials or the cladding of the building and the roof materials of the building. These are used due to that information about them should be easily accessible and is one of the requirements that has to be registered in the BBR registry which allows for easy access of information [41].

This shows that there is a difference in what building materials are used for the building and that they pose different risks and can therefore be used as an indicator for fire risk in a building.

5.4 Secondary fire indicators

In this section the last two indicators, the number of floors in a building and F-gas installation are developed. The indicators will be broken down and shown how they could be developed into fire indicators by not using statistical data.

5.4.1 Number of floors in a building

This indicator refers to the number of floors (storeys) that a building has. The hypothesis is that the more floors a building has the riskier it is. This relates to that a fires natural course is to burn vertical rather than horizontal. This might make a building that has many floors vulnerable if a fire were to occur on one of the floors as the fire could spread very fast in a vertical direction. In Figure 5.9 the risk influence factor for this indicator can be seen. The number of floors influence the possible fire spread in the building which in turn influences the risk the level of the building.

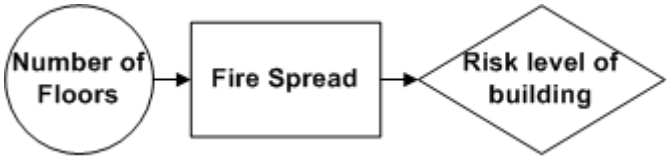

Figure 5.9: The risk influence factor for the number of floors.

Looking at Figure 5.10 there are two different buildings, one four stories high and the other one a single story building. If a fire starts somewhere in the single story building, the fire can only spread horizontally throughout the building as there is nothing above the building to catch on fire. However, if a fire were to start on the first floor of the four story building, it could be possible for the fire to spread to the second floor and then the third floor and so on. This is due to the nature of a fire spreading naturally in a vertical direction.

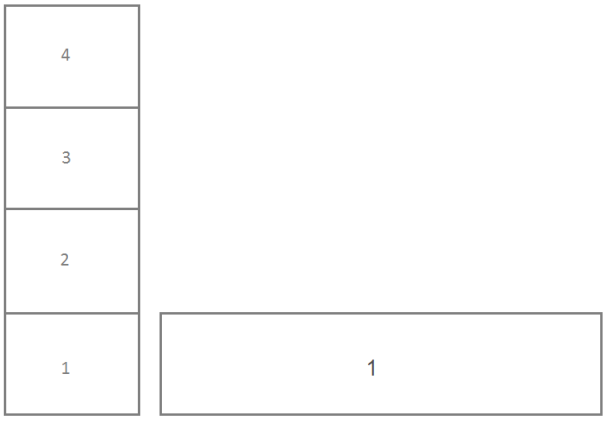

Figure 5.10: The four story building versus the single story building.

Another thing that also has to be taken into consideration is when a fire is ongoing and a smoke layer forms above the fire, the radiation from the smoke is actually going down and can therefore ignite objects or the floor to the sides of the fire that is burning. This has been illustrated in Figure 5.11 where the grey area above the fire is the smoke layer and the black arrows are the radiation from the smoke layer that can ignite objects on the floor besides the fire. Figure 5.12 shows a rule of thumb that is taught to fire fire-fighters about fire spread. It shows that fire spread in a vertical direction can take seconds, horizontal minutes and downwards in hours. This shows that although the radiation does present a risk it is not as significant as the vertical fire spread, which presents the largest risk according to this rule of thumb.

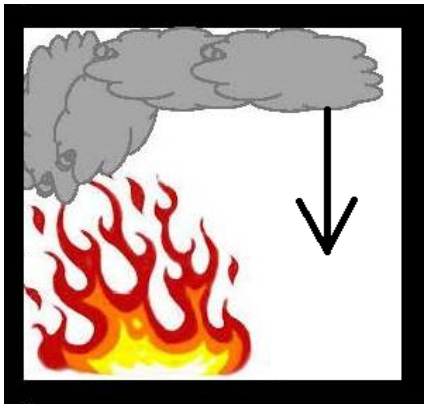

Figure 5.11: The smoke layer is at the top, with the radiation coming down as the black arrow [42].

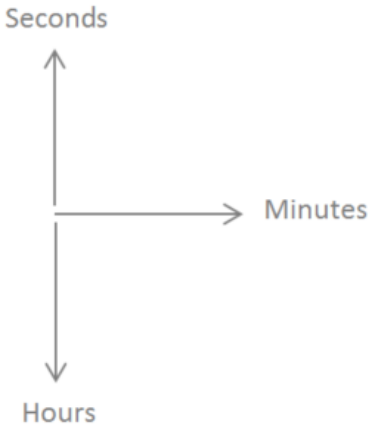

Figure 5.12: The rule of thumb for fire spread with the upward spread taking seconds, lateral taking minutes and downwards in hours.

With this information there is no way to tell how much more a building above one floor is affected by a fire than a single story building. However, with the information presented it can be said that it could potentially be worse in a building with multiple floors, all depending on where the fire starts. This can then be used as an fire indicator to distinguish between building based on the information that has been presented that a building with more than one floor represents a greater risk if a fire were to occur in it than if it were to occur in a single story building.

5.4.2 Gas installations

The hypothesis for this indicator is that in some buildings there might be some installations that use gas such as stoves, laboratories, oxygen systems for patients and furnaces. These installations that use gas can then be considered as possible ignition sources or feed a fire that has already started. The hypothesis in then that buildings that have some sort of installation that use gas present more risk than buildings that do not have installations that use gas.

Figure 5.13 shows the risk influence factors for the gas installations with the possibility of having an gas installation in the building influences the potential flammable materials as well as the ignition sources which in turn influences the risk level of the building.

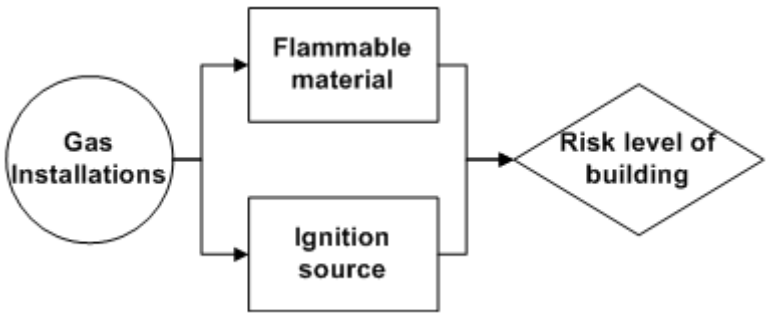

Figure 5.13: The risk influence factors for the gas installations.

There are two different legislations when it comes to buildings, the building regulations and the technical regulations. The building regulations cover all regular buildings that do not have much hazardous or flammable materials present. The technical regulations apply or take over the building regulations when one or more of the following are present in the building [56]:

- F-gas installations and storage
- Use and storage of flammable liquids
- Spray paint and painting with flammable liquids
- Timber industry
- Plastics industry
- Grain and feed industry
- Mills
- Certain other flammable companies and storages:
  - Fireworks
  - Explosives
  - Storage of pressurized containers
  - High bay storage

From this list it can be seen that the use of F-gas installation and the storage of F-gas falls under the technical regulations which means that there is an inherent danger with having those in a building.

The Danish Emergency Management Services (DEMA) classifies the F-gasses into two different types, flammable gasses and oxidizing gasses. Flammable gasses are those who can be ignited in atmospheric air and oxidizing gasses are those who have a gas or a gas mixture with more than 23% volume of oxidizing gas [57] [58].

With this in mind it can be said that a building that has F-gas installations is at more risk of having fires than buildings that do not have F-gas installations due to the nature of the gasses and therefore this will be used as an indicator of buildings either having F-gas installations or not.

Chapter 6

Development of business impact indicators

6.1 Business impact indicator selection

The set-up for developing the business impact indicators was to develop indicators that could be used to evaluate the different impacts that a business could be effected by when losing a given building. The criteria for any such indicator is that with knowledge of the indicator it should be possible to identify which of the buildings would cause the most monetary loss to the business. From the identification process it became clear that there is a difference in the identified indicators and how precisely the monetary losses can be determined. For that reason it was been necessary to distinguish between two types of indicators, listed next.

- Direct business impact indicators

  These are indicators that can be used to state a direct impact to the business from losing a building. This means that with these indicators it is possible to estimate a numerical monetary value loss. Which means that the impact is directly in the assessment, and is considered objective in measuring these impacts

- Indirect business impact indicators

  These indicators are more complex in determining the impact because they affect the cash flow of the business indirectly. The complexity of these indicators also refers to that they depend on people's perception, the specific event, what he business does and more, which also means that the evaluation of those is possibly more subjective.

Based on the difference in between the business impact indicators types, it was chosen to go through with a few of each in order to be able to use both types in the preliminary risk evaluation. From Table 4.2 five indicators were selected to move forward with into the analysis. Those are the physical losses, business interruptions, compliance, reputation and business function.

The direct indicators were chosen because they could be used to give a specific monetary value loss to the business and therefore be specific at to which of the buildings would impact the business the most. The indirect indicators were chosen because they could represent the impact the business faces, which can be hard to estimate the monetary loss from.

6.2 Direct business impact indicators

The chosen direct indicators were included because they could be used to estimate the monetary loss in numbers. There were only two that fit to this criteria and for that reason it was chosen to include them both. These indicators will be developed so that it is possible to evaluate the monetary loss that follows after a fire event.

To fulfil the requirements for them to be used as indicators, they should point to what input information should be used to estimate the monetary loss of a building. The reason for it only being an estimation is that monetary values change over time, which also emphasizes that it only represents the here and now value of the building.

6.2.1 Physical losses

The hypothesis statement for physical losses is that it can be used to determine a sum of the monetary losses to be expect from losing a building in a fire event, by stating that objects off and in the building are the ones that can be lost in the fire event. In the Danish insurance business the determination of physical losses is divided into the building and the contents of the building [50].

With the knowledge of that there is a difference in between the building and its contents, it was defined that an even further breakdown was needed to ensure that everything is included. Any input on which physical objects can be used to determine the monetary impact to the business is considered a risk influencing factor, because when they are combined it will be possible to determine the losses in monetary values. Table 6.1 shows a list of the different physical objects that have been defined to determine the monetary loss of a building.

Physical objects	Definition
1. Physical structure	The building and what insurance-wise, is considered as a part of the building.
2. Other associated structures	Other physical structures that are not encountered in the insurance of the building.
3. Equipment	Large important equipment used in the building such as industrial machines.
4. Articles	Daily used objects such as laptops, furnitures etc.
5. Artefacts	Everything made by human beings, such as products, commodities, art etc.

Table 6.1: List of different types of objects that can be lost in a fire.

One thing that has to be accounted for when determining the monetary losses from the above mentioned physical objects, is that they all might consists of several components. Meaning that physical structure as an example, might consists of several wall materials, figures etc., which all posses a monetary value. If the components are rare on the market with only a few distributors or because the materials are rare, it could increase the worth of a physical object (JS|TopDanmark; 31:16–33:38).

Another discovery that was made was that in some buildings there might be some objects that have a significantly high value, but when it comes to determining its monetary value, it is almost impossible. The objects referred to here could be a painting, old documents, sculptures, research and possibly ore (LÆK|Copenhagen University; 22:15–27:26), which could posses a substantial value, such as historical. Depending on how many copies of these objects exists and to what extent they can be recreated, they might be totally irreplaceable and therefore lost forever. The substantial objects can of course also be insured as well as the

other physical values. In these terms, the business would theoretically experience a loss of what it is insured for.

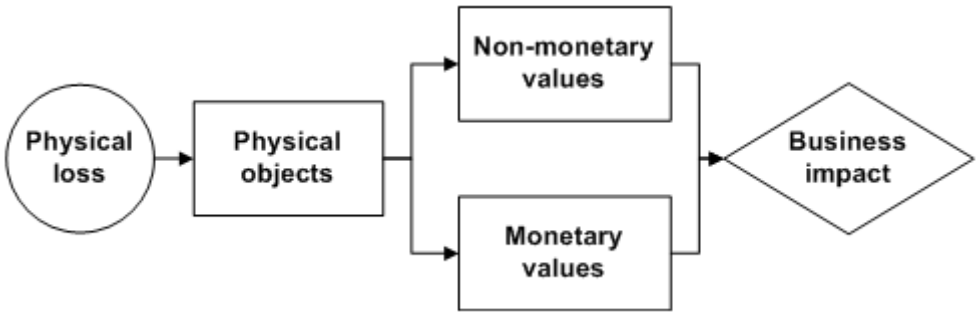

Figure 6.1: Risk influence factors for the physical losses to state the impact of a business.

Figure 6.1 shows a representation of how physical losses of a building can be used to state the impact the business might encounter from a fire event. It states that physical losses are determined by the objects of the building, which can impact the business and can be determined in monetary values and non-monetary values.

6.2.2 Business interruption

Business interruption is the loss in monetary values that the business is affected by after an event. The loss emerges when the business loses the physical ability to carry out one of its operation from where the values are made, hence, interruption of the business [59]. This is therefore different from the physical losses because it affects the business cash flow income.

The business interruption is often used in relation to insurance, which is due to that businesses want to be covered financially if an event where to happen. When insurances estimate the business interruption coverage, they use Equation 6.1 to estimate the monetary loss [60]. The equation for estimating business interruption loss uses three input parameters. Time T represent the time duration that the interruption would last. The Quantity Q is the quantity of products that are made per one time increment. The last parameter is the Value V which is the value per one quantity increment [60].

$$BI = T \cdot Q \cdot V \tag{6.1}$$

Each of the three parameters in the equation comes with complication in how the input parameters are found. T could be the time for when the building is restored, when operations are resumed or when lost earning have been captured. The Q can be different from day to day and depends on the demand for the product. V depends on the current market value of the product but does not take into account the possibility that the product might be more or less expensive in the future [60]. In other words, equation 6.1 is best used to state the loss at the time the business interruption occurs.

From the interviews that were conducted it was discovered that when businesses estimate the building that would give most monetary loss to the business, they took into if it was possible to relocate the operations to another building in the mean while. If it possible, then the loss from the building that could be backed-up would be less than if not

backed-up (LÆK|Copenhagen University: 10:00–15:30), (APM|Novo Nordisk A/S: 01:00-03:20), (JSJ|Topdanmark: 33:38–38:34) and (FD|Danish Crown A/S: 04:25-13:00).

To make the business interruption estimation useful in indication which building would impact the business the most. It would have to take into account how easy the operations are to relocate, which is also mentioned by the International Risk Management Institute (IRMI), an organization that facilitates work between risk managers and insurance. Figure 6.2 shows an influence diagram that shows a remade business interruptions estimation.

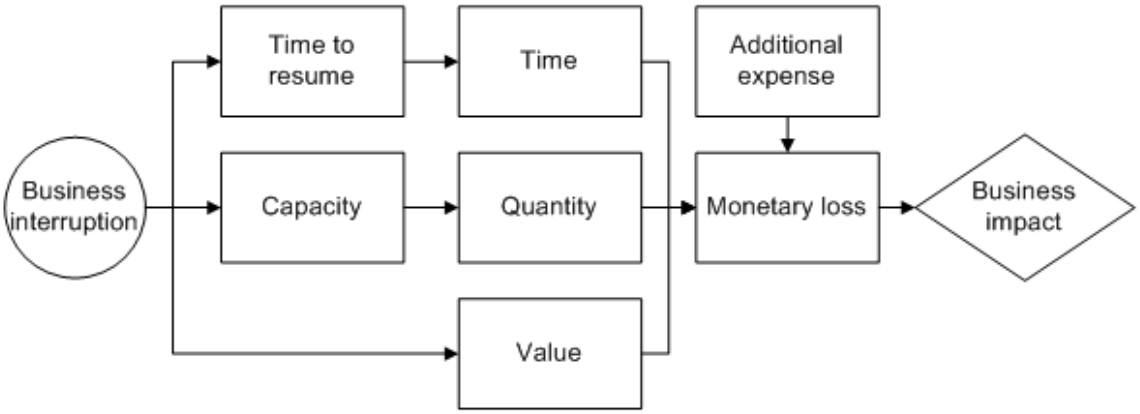

Figure 6.2: Influence diagram of business interruption estimation.

From the figure it can be seen that the T and Q are affected if the business is able to relocated the functions of the building. Furthermore, can it be read that with a relocation of the business operation, there might occur additional expenses.

If a business is going to determine which building would have the biggest impact, it should incorporate the possibility of relocating the operations. This would reduce the total loss by producing, meanwhile the old building gets rebuilt. Equation 6.2 is an updated version of the business interruptions that takes into account the relocation.

$$BI = (T \cdot Q \cdot V - (T \ - TR) \cdot C \cdot V) + AE \tag{6.2}$$

The parameter Time to Resume TR is the time from when the building is lost, until the time for when the same work resumed again. The Capacity C is the new quantity of products produced in the time increment. The Additional Expenses AE is the extra cost that follows when relocating the operation, which could be salary, rental, equipment cost and more.

6.3 Indirect business impact indicators

The Indirect indicators were chosen because they could indicate the possibility of the business to lose additional monetary values as a results from customers changing products, market share drop, loss of investors and possibly more.

These indicators should be developed such that they can indicate which buildings would indirectly have the biggest monetary loss. These indicators do for that reason include what is necessary to assess the impact.

6.3.1 Business functions

The hypothesis for this indirect indicator is that the business can be affected on its ability to compete with others by losing important business functions. According to Porter's Value chain, a business consists of a range of "Value Activities" that are divided into the listed activities. These value activities generate a competitive advantage for the business if they produce more value than what is spent on creating it, compared to the competitors on the market [30].

- **Primary activities:** These activities are the ones that create the physical value that is provided to the customers.
- **Support activities:** These activities are those that make it possible for the primary activities to be operable.

As mentioned, the primary activities provide a competitive advantage if they are carried out with low cost. If every activity is important to maintain a competitive advantage, it could be assumed that if any of those where lost to a fire, the business would be less competitive. This is according to Danish Crowns own experiences a valid concern (FD|Danish Crown A/S: 18:20-25:30).

Looking at the Value Chain in Figure 6.3, it can be seen that the primary activities are linked together in a chronological process. This means that if one of the activities are lost then the next activity might be affected and thereby the competitive advantage would suffer. The Supporting activities are the infrastructure that support the primary activities. It could therefore be possible that the primary activities are more important than the supporting ones.

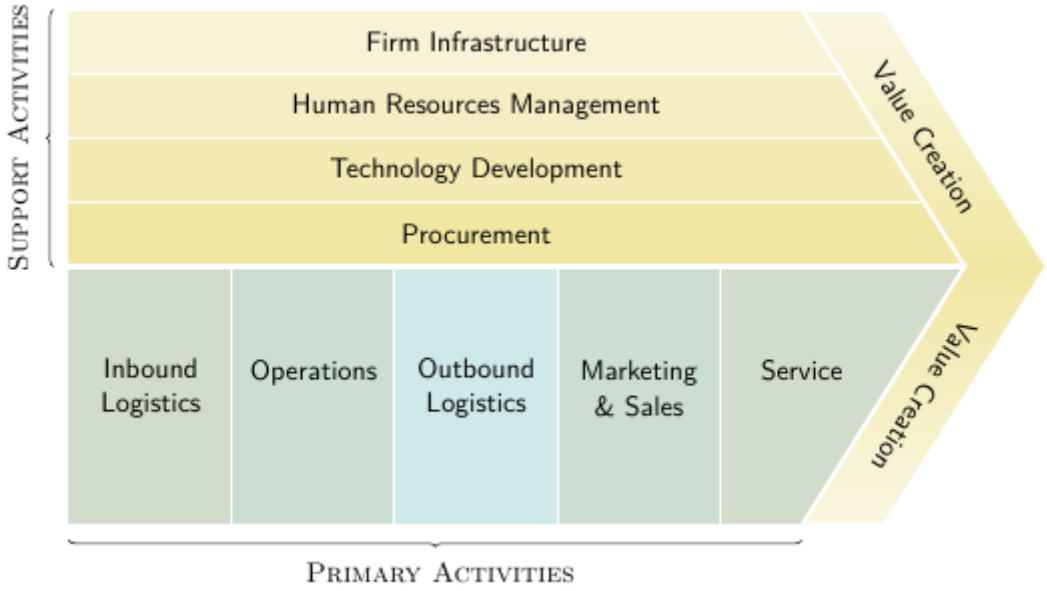

Figure 6.3: The value chain and its primary and supporting activities.

The competitive advantage is achieved by matching the customer's needs and the ability of doing so with lowest cost [30]. It could therefore be an effect, if these are not fulfilled, that

customers change products or the business gets less earnings from sales. This emphasizes that competitive advantage is about the economic survival for the business [61].

With the knowledge gained it can be said that the business functions play a key role in how the business performs when compared to its competitors. The factors that the businesses are influenced by are the businesses abilities to compete with customers needs and the cost effectiveness of activities. This is also reflected in Figure 6.4.

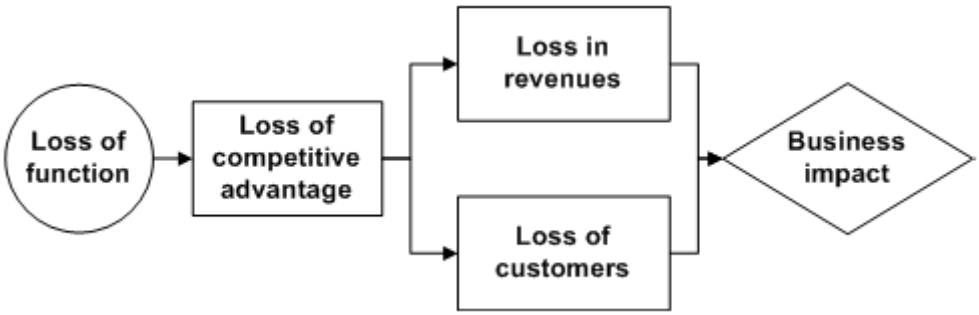

Figure 6.4: An influence diagram of the building functions.

6.3.2 Reputation

The hypothesis with reputation is that a damaged reputation affects the business with financial impact. Reputation is one of the factors according to Novo Nordisk that should be evaluated on when determining what the impact to the business would be (APM|Novo Nordisk A/S:10:10–15:55). Furthermore, according to a world-wide evaluation of the highest ranked risks for businesses made by Aon, show that reputation was ranked as the number one factor to be concerned about [62].

According to Aon's evaluation, there is a lack in tools to manage the reputation effectively [62]. Proper management of the reputational damage would assess the businesses reputation in specific subject matters, towards its stakeholders and how they would perceive its actions or lack hereof [48]. Stakeholders which could be included in an assessment have been identified in Figure 6.5.

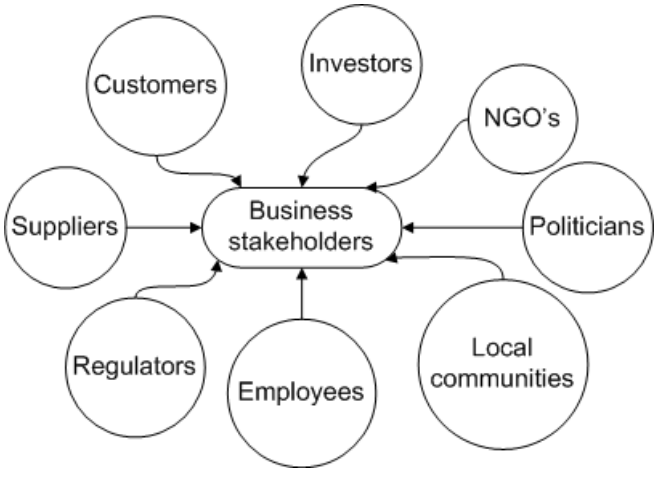

Figure 6.5: Business stakeholders that can affect the reputation [48].

It might be familiar that a good reputation among stakeholders can be beneficial for specific situations. This reflects that a good reputation has to be kept for the stakeholders in relation to various situations [48]. That being said, reputation is based on human perception, which emphasizes that the outcome from an event, might not be directly related to a specific stakeholder but still have an indirect effect.

In order to determine the reputational impact to the business from the stakeholders, it is important to determine what their individual influences on the business would be [48]. A survey made by Deloitte in 2013 pointed to that a negative impact on the reputation of a business had the biggest influencing effect on the revenue/earning and the loss of brand value [63]. Figure 6.6 shows a simplified representation of how a businesses performance generates opportunities or risks, depending on how it meets the stakeholders expectations [63].

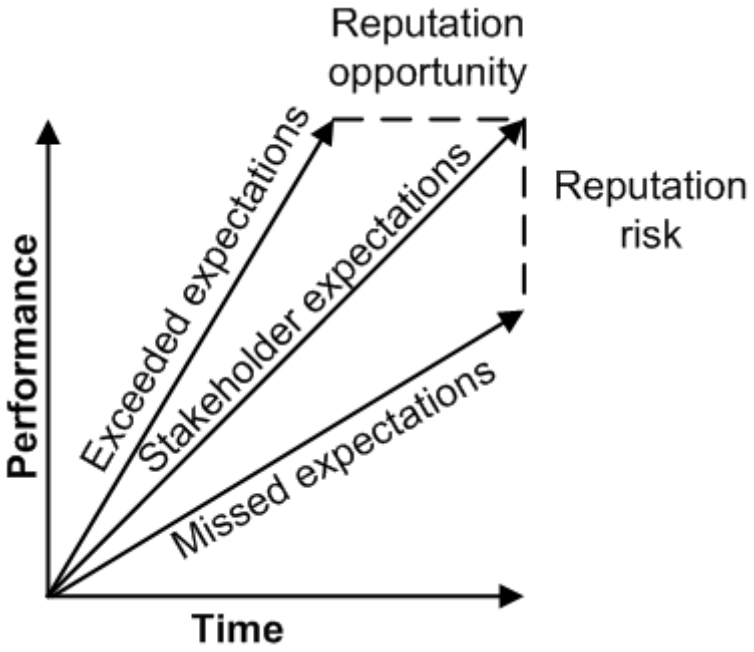

Figure 6.6: The business's performance over time and how the risks and opportunities are met with stakeholder expectations [63].

Since a businesses reputation is evaluated by its stakeholders in specific performances, where a lack in one of the performances might lead to a change in perception of the stakeholder and thereby also their actions to the business [63]. Below are listed a few of the performance situations that have been identified that could be relevant to some of the stakeholders previously mentioned [48] and [63].

- Environmental and social.

  This often falls under the category of Corporate Social Responsibility (CSR). The trend today is that there is an increasing focus on how the environment is treated and also what business's do to lift social responsibility. This leads to that business's have to be careful to not get a reputation as the bad guys.

- Quality of product.

  The quality of the product and/or services are important to the customer, where it has been identified that if the product affects the health of the customer, then performances

in other situations might as well influence the customer's choice in the end. This leaves business's like pharmaceutical companies very exposed to reputational loss which leads to loss of customers.

- Compliance with laws and regulations.

  If business does not follow the legal compliances that it was supposed to, it can lead to reputational damage. Customers might be offended, doubt the products quality and it might make them choose other alternatives instead, which also affect the shareholders trust.

- Financial performance.

  The financial performance of customers, are important to the business, shareholders and investors. Because if a business has a bad performance in finance it might make the shareholders and investors decisions to putt money into the business, which in the long run would affect the businesses sustainability.

- Ethics and Integrity.

  Businesses that perform with good ethics and integrity are deemed more trustworthy for different stakeholders. Which can emphasize that if this trust is betrayed, it could scare shareholders, investors, customers and other stakeholders from not supporting the business.

These performances situations are just a few that a business is evaluated on by its stakeholders but never the less important to mention. Practically, it would seem to be better to make an assessment of situations and stakeholder specific businesses.

It is also important to remembers that the performances situations can also be opportunities for businesses and act like safety barriers for damaging the reputation severely. Even in the situations where the initial performance has failed, the crises performance might be able to redeem some of the reputational damage caused by the event [63].

From this analysis it should be clear that the risk influence factors of reputational indicators for stating an impact to a business depend on the stakeholders and the performances in situations the business encounters. Figure 6.7 is made to make it clear how the reputational risks can be assessed for their impacts to the business. What should be noted from the figure is that one event can lead to a cascading impact to the business, where example, loss of customers could lead to loss of investors [48].

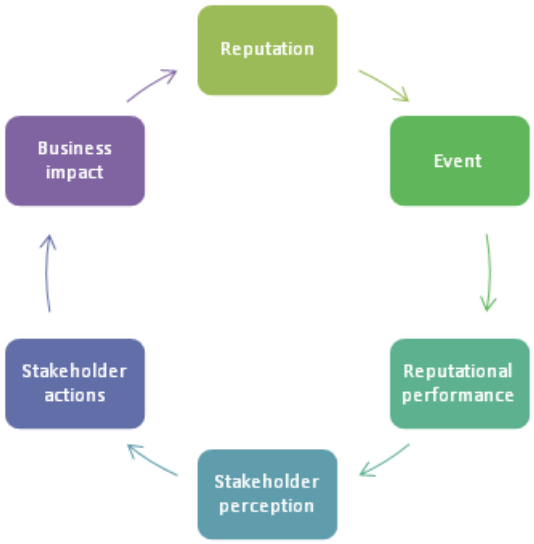

Figure 6.7: The cycle of how reputation can be damaged by an event and lose the reputation to its stakeholders.

6.3.3 Compliance

The hypothesis for Compliance is that if a building is lost then it could affect the business ability to comply with its binding agreements and then impact the businesses cash flow. To understand this better, a further look into what compliance is, is needed to define how a non-compliance could affect the business.

Compliance risks for businesses can be if the business fails meet the requirements from certain regulations or laws [64]. But what every business also should have an interest in, is being in compliance with customers, shareholders, deliveries etc. Because these can impact the business on its market values, sales, loyalties of customers and the ability to keep operational functions running. These all fall under the four effects categories that Deloitte has defined and are described below [65].

- Legal effect

  Legal effect is when employees or the business fails to comply with regulations and can lead to fines, penalties or other regulatory punishments for such non-compliances [65].

- Financial effect

  The financial effect is the effect the businesses cash flow goes through and can be caused by the compliance with product deliveries to customers or investors/shareholders expectations with the financial performance are not meet. This would leave the business with a reduced monetary income [65].

- Business flow effect

  Business flow effect in this context refers to the core functions of the business that can be affected. Where failure to comply with regulations and internal procedures can lead to that the business would lose one of it functions and thereby the effectiveness of the business value creation [65].

- Reputational effect

The reputational effects of the business are damages to the brand of the business and leads to a stakeholders dissatisfaction. A failure to comply with the business public image would cause damages to the brand [65].

It could be understood from the previously mentioned four compliance impact areas that the impacts are determined to which stakeholders the compliance risks involves as well as to what their concern is. This makes the assessment of compliance risks very individual from business to business, because where in one business the compliance risk might be very strict in quality from the laws (external) where for others it could be more internally determined [65].

Defining the exact impact the business would suffer from a failure to comply depends on the core of the compliance area and whom it involves. That is why most assessments made today rely on the businesses own ability to identify compliance risks within their respective field, in the same time such assessments are also often made with descriptions of cascading effects from an event. Therefore, the challenge in making the compliance impact indicators lies within making the complexity of compliances risks impacts, preliminary measurable.

In order to make the compliance impact measurable it is needed to define what risk influence factors the compliances impact would be measured on. As stated, there are many different compliances that can be applied to a building but some of the most important to the business were discovered from the interviews, to be related to customers delivery (APM|Novo Nordisk A/S; 03:20–04:30) or the quality of what was promised cannot be fulfilled (APM|Novo Nordisk A/S; 10:10–15:55). Also, Deloitte specifies that some of the impacts related to compliances involves the consumer on both quality issues and failure to deliver [65].

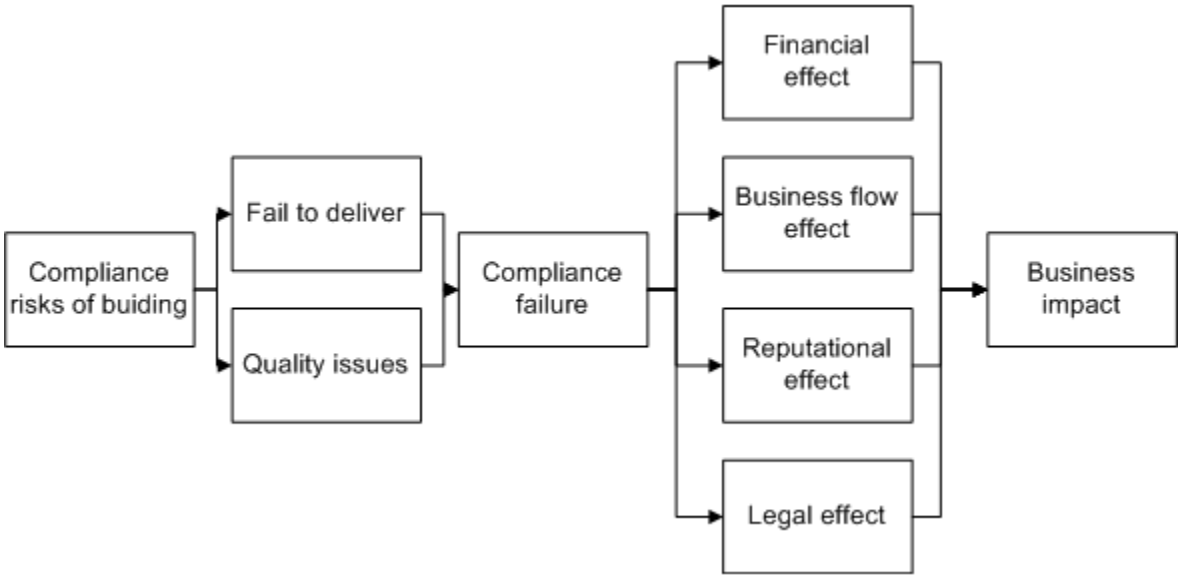

Figure 6.8: Flow diagram of compliance impact to a business.

Figure 6.8 shows a representation of a flow diagram for how compliance BII are elaborated from previous discovery. The two risk influences in this case should be used as guidance to determine what the effects from such compliance failure would be. The effects are then measured in the four effect categories, in terms of how the failure would affect the business.

Chapter 7

Developing risk scores for indicators

This chapter is dedicated to the development of risk scores for the indicators presented in Chapter 5 and 6. The indicators in those chapters only show indications and in order to be able to compare buildings the indicators have to show some sort of a risk that can be measured and compared from building to building. That is what is done in this chapter, first for the fire indicators and then for the business impact indicators.

7.1 Primary fire indicators

In chapter 5, seven fire indicators were analysed and developed to show different levels of fire distribution. Two out of those seven indicators, the number of floors and F-gas installations are based on their hypotheses rather than the fire distributions. This is because that data for those indicators is not available at the time this project is done. The risk score for these two indicators is therefore developed in another way than for the other five and is done in Section 7.2. The five indicators that the risk score can be developed in the same way are the risky rooms, size of the building, usage of the building, location and building materials and the way the risk score is developed for them is presented in this Section.

7.1.1 Severity analysis

In Chapter 5 the indicators were developed by utilizing the BRS database and by using the data there about the occurrences of fires for the different indicators. Since the indicators are developed using the number of fires it would be good if they could be connected to the risk score for each indicator. This was done by utilizing the BRS database again, by looking at the severity of fires. In the database it is possible to see the severity of the fires that are registered in the database. The severity of the fires is registered in 10 severity categories after how the fires were put out. The categories and the size of fires they represent can be seen in Figure 7.1.

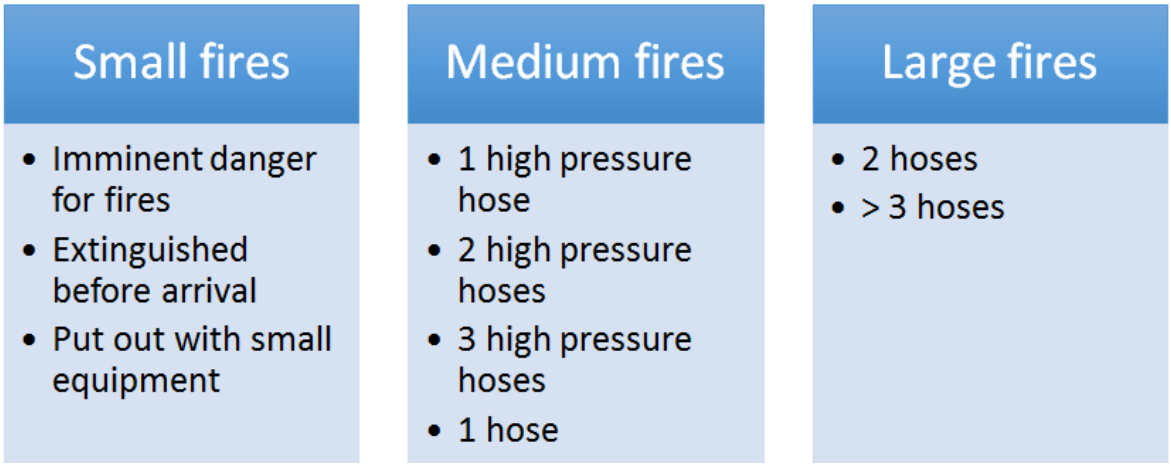

Figure 7.1: The severity categories and how they are split up into small, medium and large fires [43].

According to the BRS database this is how the fires are split up into small, medium and large fires based on how they were put out. The last category is called unknown and represents that knowledge about the size of these fires is not known. Small fires are those where the fire department does not have to do to much when they arrive as the fires have mostly been put out before their arrival or is an imminent danger for fire. Medium fires, are those where the fire department has used high pressure hoses to put out the fires and uses more water to put out the fires than in the small category. Large fires are those where the fire department uses multiple large hoses that are connected to a fire hydrant, which increases the water usage which means that those fires are large. To show this distribution an example is provided for the risky rooms indicator.

Table 7.1 shows how many fires were small, medium or large for the five rooms that have the most fires in the primary business industry category.

Room type	Small fires	Medium fires	Large fires	Total with unknown
Barn	17	159	610	802
Stable	32	120	304	465
Boiler room	42	163	94	304
Machine house	5	50	166	227
Chimney	57	7	3	68

Table 7.1: The table shows the number of small, medium and large fires for the five rooms that have the most fires in the primary business industry category.

Knowing the number of fires that were small, medium or large is the first step towards developing a risk score for the indicators. With these numbers it is possible to find the distribution of small, medium and large fires out the total amount of fires for each room. However, the distribution is possibly not the best way to use as a risk score as it only covers the distribution of small, medium and large fires within each room and does not represent the the risk of said room. Therefore it was decided to develop risk weights for the different sizes of the fire. These risk weights are presented in the next section.

7.1.2 Risk weights

In order to give the different indicators a risk score, a risk weight system has been devised. This is done so that the indicators have a risk score and the buildings can be prioritized based on the risk score they get from the different indicators. The risk score for the fire indicators is based on the sizes of the fires for each indicator [66]. The different sizes of fires are given a weight that is then used to get the finalized risk score. The weights are:

- Small fires = 20
- Medium fires = 40
- Large fires = 100

The weights are associated to the sizes of the fires by subjective opinions of what the consequences of the fires could be. A small fire does not represent a big damage to a building as they only represent fires that were either put out with small fire equipment, extinguished before the arrival of the fire department or was an imminent danger to become a fire, therefore the weight of 20 is assigned to small fires. The medium fires get a weight of 40 because they represent more severe fires than the small ones and more water is used to put out the medium fires than the small ones. Large fires get a weight of 100 as they represent more severe fires than the small and medium and a lot of water is used to put out these fires. Generally the bigger a fire is the more water has to be used to put it out.

It is important to note that these weights are selected by the authors and generally depend on the risk perception of whoever is assigning the weights. The results of the risk score will always be sensitive to the weights put on the different sizes of fires as they are based on subjectivity. The weights of 20,40 and 100 are chosen over any other combination of weights because that these weights show the difference in the sizes of the fires the best. This is because that a small fire should have an impact but not so much and therefore a weight of 20 has been chosen. A medium fire signifies a somewhat large impact and is therefore twice the size of the small impact and finally the large impact is considered to be a high impact and therefore it should have the highest possible score of 100 and represent a significantly larger impact than the medium one.

Continuing on with the example presented in Table 7.1 which shows the distribution of small, medium and large fires out of the total fires, Table 7.2 has been made.

Room type	Small fires	Medium fires	Large fires
Barn	0.021	0.198	0.760
Stable	0.069	0.258	0.654
Boiler room	0.138	0.536	0.309
Machine house	0.022	0.220	0.731
Chimney	0.838	0.103	0.044

Table 7.2: The table shows the distribution of small, medium and large fires for the five rooms that have the most fires in the primary business industry category.

Taking the information presented in Table 7.2, an event tree of the risky room, Barn, is made in Figure 7.2. The figure shows the distribution of Barn fires out of the total fires as 0.0799. Then how the small, medium and large fires are distributed from the total number of Barn fires and the risk weights associated with the sizes of the fires. When the risk scores

for the small, medium and large fires have been calculated it is possible to use the number 0.0799 to get the expected risk score of the Barn by multiplying it with the sum of the risk scores for the small, medium and large fires to get a total risk score.

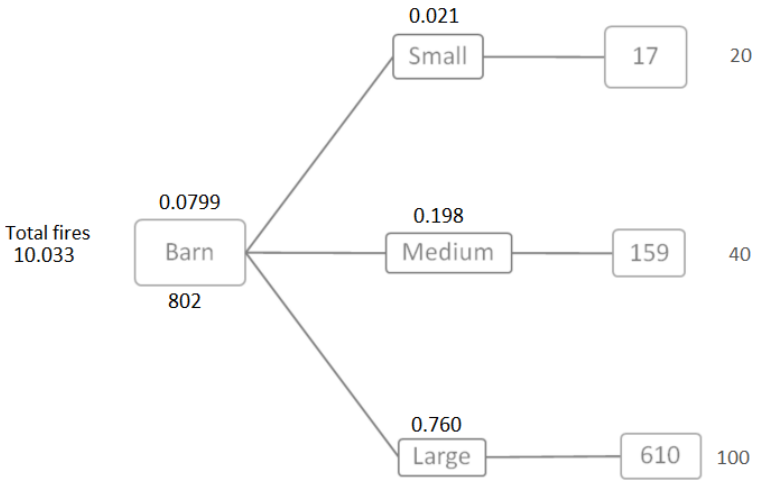

Figure 7.2: The event tree for the barn as a room.

Using the numbers presented in the event tree in Figure 7.2 the risk score for the Barn can be calculated, the calculation for the risk score of the sizes of fires is shown in Equation 7.1.

$$Size\ fires\ distribution \cdot size\ risk\ weight = Size\ risk\ score \tag{7.1}$$

For the small fires for the Barn the risk score will be calculated as is shown in Equation 7.2

$$0.021 \cdot 20 = 0.42 \tag{7.2}$$

Equation 7.1 is then used to calculated the risk score for the medium and large fires as well. Table 7.3 shows the risk scores for the small, medium and large fires for the five rooms that have the most fires in the primary business industry that have been presented earlier.

Room type	Small risk score	Medium risk score	Large risk score	Risk score sum
Barn	0.42	7.930	76.059	84.414
Stable	1.376	10.322	65.376	77.075
Boiler room	2.763	21.447	30.921	55.131
Machine house	0.441	8.811	73.128	82.379
Chimney	16.765	4.118	4.412	25.294

Table 7.3: The table shows the risk scores and risk score sum of small, medium and large fires for the five rooms that have the most fires in the primary business industry category.

The small, medium and large risk scores are then summed together to get the risk score sum and this risk score sum is then multiplied with the distribution of fires for each room out of the total amount of fires. Table 7.4 shows the distribution of fires out of the total fires, the risk score sum and the total risk score for each of the five rooms.

Room type	Distribution of fires	Risk score	Total risk score
Barn	0.0799	84.414	6.748
Stable	0.0463	77.075	3.572
Boiler room	0.0303	55.131	1.670
Machine house	0.0226	82.379	1.863
Chimney	0.0068	25.294	0.171

Table 7.4: The total risk scores for the five rooms that had the most fires in the primary business industry.

Table 7.4 shows the risk scores for the top five rooms in the primary business industry. The same method of calculating the risk scores is used for the rest of the rooms and the other four indicators that risk score can be calculated for. The risk scores for all of the indicators can be seen in Section 7.3. In the next section, the two secondary fire indicators that the risk score can not be calculated in the same way, are presented.

7.2 Secondary fire indicators

There are two indicators that can not be given a risk score the same way as was done in the previous section, these there indicators are:

- F-gas installations
- Number of floors in a building

The F-gas installations refer to if a building has some F-gas installations or not. Therefore a building that has F-gas installations should get a higher risk score than a building that does not have any. If data for this indicator was available it could be calculated like the others by finding out how many fires have been caused by F-gas installation and what sizes of fires they have caused. Then it could be possible to develop the risk score for this indicator the same way as has been done for the others. Since there is no data available for how severe fires caused by F-gas installations have been or the number of fires, the risk score will be based on subjective opinion. Because it is based on subjective opinion it should be reflected in the score as well.

The number of floors in a building refer to that the more floors a building has, the more risk is of fires and the spread of the fire can be bigger when the number of floors increase. However, since there is no available data about how fires are distributed over the floors of a building and the fire spread of those fires, this indicator will have to be scored on subjective opinion. If data were available, the way this indicator could be developed and scored is by first finding out the number of fires for single storey buildings as a base mark. Then finding out how many fires have occurred in a two storey building, three storey building etc to compare to the base value of the one storey building. To get a risk score, the sizes of the fires would have to bee looked into next to see if there is a difference in the risk of having a single story building versus a two story building and if a three story building is worse than a two story building and etc.

The F-gas installation indicator will therefore be used as either you have F-gas installations or not and the number of floors indicator will be used as either you have more than one floors or not. The risk score for having F-gas installations is set to 0.5 and the risk score for having more than one floors is 0.5 as can be seen in Table 7.5.

Indicator	Yes	No
F-gas installations?	0.5	0
More than 1 floor?	0.5	0

Table 7.5: he risk scores for having F-gas installations and for having and not for having more than one storey building.

The risk scores are selected as being one because a risk score of 0.5 is not much higher than a score of zero and by setting the scores to 0.5 a little cap can be created between having those indicators or not having them, which also says that these indicators are possibly not the most reliable ones they can still be used to help in the quest of prioritizing building. Their impact on the total risk will just be lower than some of the other indicators.

7.3 Risk score results for the fire indicators

In this section the results for the risk scores of the fire indicators will be presented. The results will be presented one by one, for all of the indicators. Table 7.6 shows the risk score results for the risky rooms split up into business types.

It can be seen from the table that the risk scores differ from room types after what industry is being looked at. This states that there is a difference in the risk of the rooms and after what industry they are in as well. The rooms with the highest scores in each industry are, Barn, Stock room, Kitchen, living room and Stock room in the order from primary to other.

Room	Primary	Secondary	Tertiary	School fires	Other
Assembly room	0.022	0.020	0.785	0.239	0.026
Barn	6.748	0.106	0.161	0.000	0.074
Bathroom	0.006	0.038	0.361	0.157	0.030
Bedroom	0.032	0.000	0.598	0.028	0.002
Boiler room	1.670	0.512	0.163	0.060	0.068
Chimney	0.171	0.086	0.030	0.000	0.006
Cleaning room	0.004	0.012	0.070	0.022	0.010
Elevator	0.004	0.014	0.014	0.000	0.000
Entrance	0.022	0.032	0.213	0.078	0.048
Garbage room	0.000	0.116	0.152	0.062	0.044
Hallway area	0.012	0.030	0.245	0.098	0.036
Hobby room	0.086	0.004	0.042	0.078	0.008
Kitchen	0.098	0.241	2.083	0.138	0.157
Laboratory	0.014	0.064	0.022	0.034	0.020
Common area	0.476	0.086	1.900	0.319	0.138
Machine house	1.864	0.496	0.120	0.034	0.054
Office	0.038	0.165	0.263	0.066	0.148
Sales area	0.000	0.134	0.799	0.000	0.110
Sauna	0.000	0.002	0.056	0.002	0.000
Scullery	0.014	0.012	0.008	0.000	0.008
Silo	0.271	1.092	0.189	0.014	0.050
Spray booth	0.000	0.283	0.030	0.000	0.052
Stable	3.572	0.016	0.014	0.000	0.002
Stairs	0.002	0.010	0.090	0.012	0.014
Stock room	0.429	2.137	1.655	0.040	0.431
Storage room	0.076	0.122	0.532	0.231	0.100
Storage, ceiling	0.110	0.048	0.189	0.034	0.014
Storage, cellar	0.000	0.014	0.100	0.032	0.018
Technical room	0.098	0.582	0.393	0.086	0.080
Underground parking	0.000	0.002	0.044	0.012	0.012
Waiting room	0.010	0.002	0.026	0.000	0.002
Wardrobe,locker rooms	0.000	0.020	0.122	0.022	0.030
Workshop	0.359	1.958	1.214	0.088	0.429

Table 7.6: The risk scores for the rooms split up after business types.

Table 7.7 shows the risk scores for the size of a 10.000 m^2 building with the usage taken into account. The size is multiplied with the frequency of the given usage categories to get the expected fires per year given a 10.000 m^2 building. That value is then multiplied with the risk score of the usage category to get the total risk score for a 10.000 m^2 building in the different usage categories. This is an example of how the risk score for the size of the building is calculated and is done to show how this indicators would be used. For this given example, a building of 10.000 m^2 has the highest risk score in the residential care usage category, which is due to that the frequency of fires is the highest for this category.

Industry	Size (m^2)	Frequency (Fires per year)	Risk score	Total risk score
Residential care with permanent stay	10.000	1.34E-04	4.000	**5.36**
Farming and operational	10.000	1.78E-06	16.704	**0.297329**
Factories, workshops, etc	10.000	3.11E-06	8.073	**0.251065**
Electricity, gas, water and heating plants	10.000	9.27E-06	1.699	**0.1575**
Transport or garage	10.000	5.06E-06	1.835	**0.092849**
Offices, trade, warehouse and public admin etc	10.000	1.32E-06	3.680	**0.048571**
Hotels, restaurants, hairdressers etc.	10.000	8.83E-06	2.150	**0.189888**
Libraries, churches, museums etc.	10.000	4.84E-06	0.981	**0.04746**
Teaching, research etc.	10.000	3.12E-06	2.466	**0.07694**
Hospitals etc	10.000	6.19E-06	1.220	**0.075499**
Day care centres	10.000	6.43E-06	0.937	**0.060242**
Sports houses, clubhouses etc	10.000	2.77E-06	0.757	**0.020977**
Other	10.000	3.34E-06	5.932	**0.19813**

Table 7.7: The risk scores for a building that is 10.000 m^2 and the calculated risk scores which incorporates the different usage categories.

Table 7.8 shows the risk scores for the 16 usage categories. The usage categories refer to the usage of the building, or what it is being used for. The buildings that are used for farming and operational purposes have the highest risk score and three categories do not have a score as there is no data available for them.

Building usage	Risk score	Building usage	Risk score
Residential care with permanent stay	4.000	Unspecified transport and trade	-
Farming and operational	16.704	Libraries, churches, museums and etc	0.981
Factories, workshops and etc	8.073	Teaching, research and etc	2.466
Electricity, gas, water and heating plants	1.699	Hospitals etc	1.220
Other buildings for production	-	Day care centres	0.937
Transport or garage	1.835	Unspecified institutions	-
Offices, trade, warehouse, public admin and etc	3.680	Sports houses, clubhouses and etc	0.757
Hotels, restaurants, hairdressers and etc	2.150	Other	5.932

Table 7.8: The risk scores for the 16 different usage categories.

Table 7.9 shows the risk score results for the different industries based on location. In the table it can be seen that there is a difference in the industries risk scores base on where they are located in Denmark. The highest being tertiary in the capital area and the lowest in the other category for North Jutland.

Region	Primary	Secondary	Tertiary	School fires	Other
Capital area	0.052	0.094	0.662	0.388	0.136
Zealand	0.317	0.110	0.536	0.187	0.169
North Jutland	0.148	0.044	0.140	0.056	0.028
Mid Jutland	0.319	0.050	0.326	0.130	0.120
Southern Denmark	0.315	0.086	0.495	0.218	0.167

Table 7.9: The risk scores for the different industries based on the location.

Table 7.10 shows the risk scores for having or not having flammable roof of wall materials. The materials are split up into to to categories, roof materials and wall materials with the roof materials giving a higher risk score if the building has flammable materials.

Indicator	Yes	No
Flammable roof material?	2.241	0
Flammable wall material?	0.872	0

Table 7.10: The risk scores for having and not having flammable roof or wall materials.

Table 7.5 in Section 7.2 shows the risk scores for the secondary indicators F-gas installations and the number of floors. With having F-gas installations giving a risk score of 0.5 and having more than one floor giving a risk score of 0.5 as well.

7.4 Introducing safety measures

Now that the FI's has been developed a wondering had emerged from the research conducted, this wondering is based on that the risk score does not take into account if there has been implemented any safety measures in the building. Neither was it the intention project was initiated, but it has been acknowledge that it might be an important factor to introduce.

Safety measures of a building is important to introduce due to that if they already are to be identified in a building, then that could cause a reduction in the FI risk scores. The reduction could be implemented in the risk score calculation where it could both have a reducing effect on the likelihood of the fire occurrence as well as to how severe the fire would get. In a broader elaboration of the risk assessment process safety measures would be introduced as Risk Reduction, which is initiated based on acceptance criteria on the risk evaluation, which can be seen in the updated Figure 7.3 from BSI.

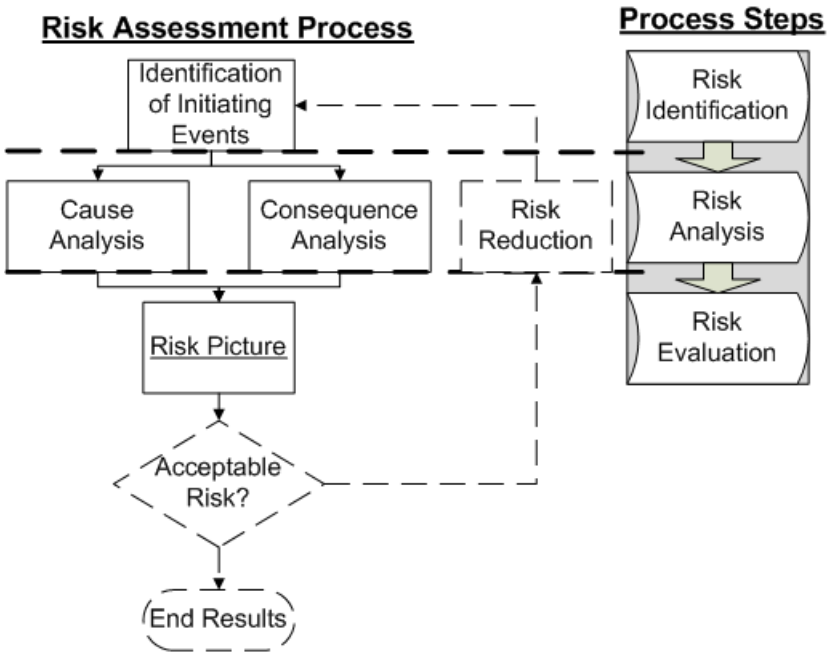

Figure 7.3: Updated risk assessment process, with decision making and risk reduction step added(BSI).

A preliminary research into different safety measures revealed that there is at least three categories of safety measures. There are the active and passive fire protections which is also

included in the Danish fire and building regulations, but there is also the ones that requires peoples action and are procedure based. some of the identified safety measure can be seen in Figure 7.4.

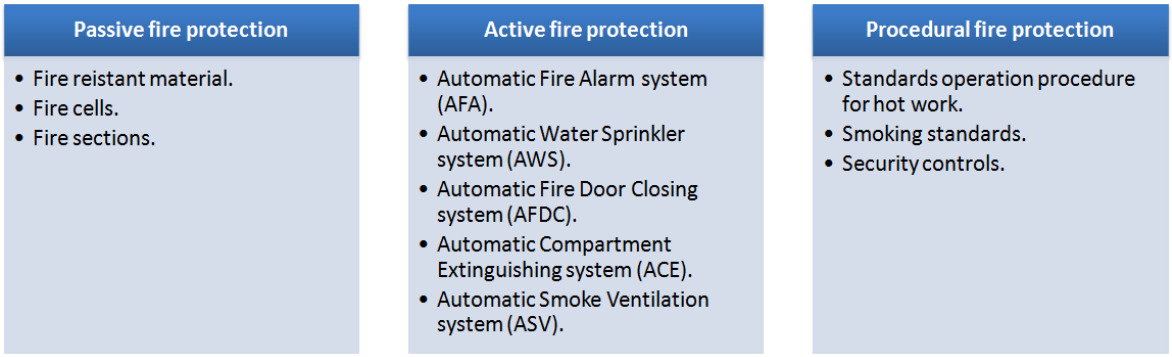

Figure 7.4: Safety measures identified from preliminary research.

Just to put the safety measures into perspective on what safety measures effect could be on the risk score, in Figure 7.5 is a recreation of a handout by NIRAS. It shows that there is a correlation between that building with a AFA system installed might have an effect on the severity of fires. This could make a change in the risk scoring carried out in the previous chapter, but because of the scope of the project it is excluded for the time being.

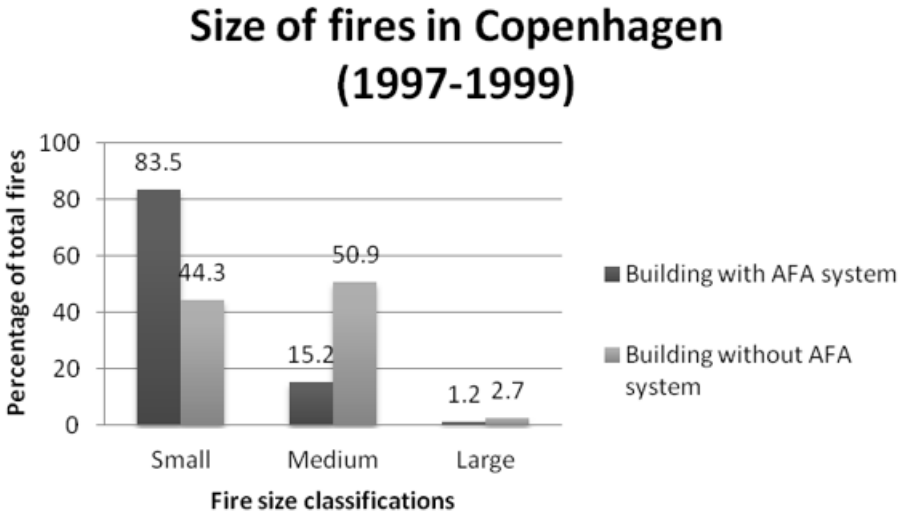

Figure 7.5: The diagram shows the difference between building with AFA system installed and without them, in relation to how server the fire gets. It is a recreation of document handed out by NIRAS.

7.5 Business impact indicators

In the previous section, the fire indicators measurements for a risk evaluation was based on the probability distribution in order for them to reflect the reality. Using the same idea for the measurements of the business impact indicators would be ideal. But as was concluded in Chapter 6, there is two types of business impact indicators, which represent how complex

the impact is to evaluate. Those types where called direct and indirect business impact indicators. It became clear that these two indicators should be evaluated in different ways and their measurements should therefore also be assigned differently. The Direct indicators are mainly based on the monetary losses from losing a building and are therefore more objective in perception. Where on the other hand the indirect indicators rely on the reaction that follows after the event has occurred and the specific scenario.

7.5.1 Direct business impact indicators

The direct indicators are the ones that can be used to state how big the monetary loss from losing a building would be to the business. These indicators are divided into the immediate loss expected from losing physical values and the long term expected loss. These impacts can be estimated by measuring different indicators that was previously stated and in the end will be added together, which means that the business impact is estimated by Equation 7.3.

$$Total\ estimated\ monetary\ loss = Physical\ loss + Business\ Interruption\ loss \tag{7.3}$$

In order to make this estimation give as close an approximation as possible it is important to know what values to include in the equation. For both of the indicators this was presented in Chapter 6 and for the physical loss indicators there were five things to account for when determining the monetary loss, which is iterated in Table 7.11.

Physical objects	Definition
1. Physical structure	The building and what insurance-wise, is considered as a part of the building.
2. Other associated structures	Other physical structures that are not encountered in the insurance of the building.
3. Equipment	Large important equipment used in the building such as industrial machines.
4. Articles	Daily used objects such as laptops, furnitures etc.
5. Artefacts	Everything made by human beings, such as products, commodities, art etc.

Table 7.11: List of different types of object that can be lost in a fire.

What one has to be aware of is that the monetary values of the different objects might change over time and could for example be due to material prices changes. That means that the monetary value today is not the same as tomorrow, but for a preliminary risk evaluation this is decided to be close enough. It might also be so that there are other monetary values that are not considered in the table, which is why a sixth input would be Others, where other monetary values can be summed in. When it comes to the Business interruption indicators, the inputs for the risk assessment are found in Equation 7.4 where each parameter of the equation is an input to the risk assessment.

$$BI = ((T \cdot Q \cdot V) - (T\ -\ TR) \cdot C \cdot V) + AE \tag{7.4}$$

With the parameters from the business interruption equation, the inputs needed to make an estimation of monetary loss from losing a building are described in Table 7.12. It should be noted that these two indicators are similar with most of the fire indicators as they are based on objectivity and therefore limit the amount of people's perception of what monetary values are.

Input parameters	Definition
Time (T)	Time duration from when the building is lost to when it has been reconstructed.
Quantity (Q)	The quantity of products produced per T increments.
Value (V)	The monetary value for each Q increments.
Time to Resume (TR)	The time duration it takes to resume the activities in another place.
Capacity (C)	The capacity for Q in a new location
Additional Expense (AE)	The extra expenses that it would cost to move the production, and maintain it in another building.

Table 7.12: The table shows the inputs and their definitions in order estimate the Business interruption.

7.5.2 Indirect business impact indicators

The indirect indicators were the indicators that had an impact on the business, but were more difficult to state exactly how much the impact would be. There were three indicators identified which measurements for, are developed in this section.

Because that these indicators do not state a specific impact and it is difficult to define how much the impact would be without knowing the business. It was decided that these indicators should be measured with subjective knowledge, that could be brought forth by a person from the business that is evaluated. This decision is also due to that knowledge about the business reputation, compliance effect and business function are likely better known by the business than people from outside.

The way that the subjectivity can be measured is by applying scores that each of the indicators are measured in. The scoring method can be developed in various ways with several numerical values. However, in this project it has been chosen to use a five scale scoring where one represents the lowest score. The individual basic definitions of the scoring scale can be seen in Figure 7.6.

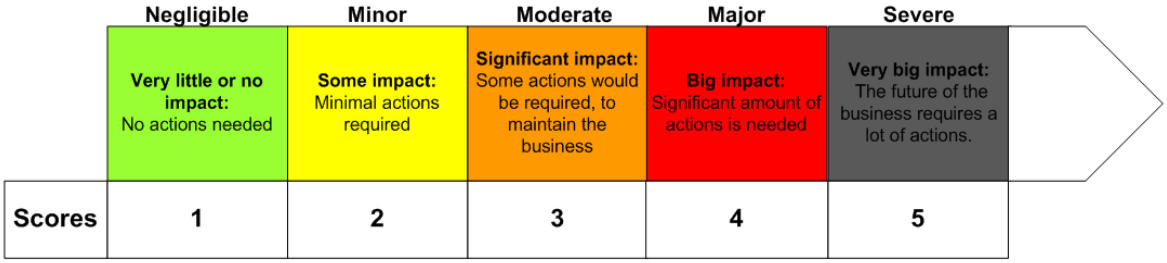

Figure 7.6: The five scale risk scoring diagram to evaluate the indirect indicators.

Now that the scoring scale has been made, it should be made applicable to evaluate the impact to a business from each of the three indirect indicators. The evaluation of the indicators would be made by asking the right questions that the business would need, to evaluate the business impact. This is a method often used to make preliminary risk evaluations and it gives a degree of freewill to measure the buildings in relation to each other. It is necessary to evaluate them in comparison to each other such that they can be compared on the same basis. In Table 7.13, there are defined questions that could be used to determine the severity of an impact of the three indirect indicators. These are as said before dependant on subjectivity and do not represent an emptying list of possible questions as there might be some more questions that have not been included or thought of.

	Impact scoring				
Impact indicator questions	**Negligible**	**Minor**	**Moderate**	**Major**	**Severe**
Building function					
1. How important is the building to keep a competitive advantage to attract customers?					
2. How important are the buildings functions in creating a better revenue than competitors?					
Reputational damage					
3a. To what degree could the loss of a building affect the environment?					
3b. To what degree could the loss of a building affect the social responsibility the business is committed to?					
3c. How important is a good environmental and social responsibility reputation to the business?					
4a. To what degree could the loss of a building affect the quality of the product?					
4b. How important is the product quality for the business to its stakeholders?					
5a. To what degree would the loss of the building affect the business to be in compliance with laws and regulations?					
5b. How important do the business stakeholders think the compliance is?					
6a. To what degree would the loss of the building affect the business financial performance?					
6b. How important is it for the stakeholders that the business performs well?					
7a. To what degree would the loss of the building affect the ethics and integrity of the business?					
7b. How important are ethics and integrity for the stakeholders of the business?					
Compliance					
8a. To what degree would a failure to deliver affect the business financial compliance?					
8b. To what degree would a failure to deliver affect the compliance of the business's other operations?					
8c. To what degree would a compliance failure to deliver, affect the reputation of the business?					
8d. To what degree would a failure to deliver affect the legal compliances of the business?					
9a.To what degree would a failure to comply with proper quality of products lead to a financial impact?					
9b. To what degree would the business flow be impacted by a failure to comply with proper quality?					
9c. To what degree would a failure to comply with proper quality of products lead to a reputational impact?					
9d. To what degree would a failure to comply with proper quality of products lead to a legal impact?					

Table 7.13: The indirect indicator questions that are used to determine the impact to the business.

Chapter 8

Implementing the indicators

From the previous chapter the developed indicators were made such that they could be used with numerical measurements in a risk evaluation. This leads to the last part of the problem solution, which is to make use of the indicators in a risk assessment process. The chapter will seek to explain how the indicators can be implemented in such an evaluation and to show how it would help the building owners to prioritize one building from another.

8.1 Using the indicators

The intended use of the indicators is to use them in some sort of a tool that can be used to differentiate between the risks of multiple buildings and establish preliminary risk evaluations of the buildings. The risk evaluations of the buildings can be compared to find out which building has the highest fire risks according to the fire indicators and the highest business impact according to the business impact indicators.

As can be recalled from Section 3.1, that the risk assessment process is four steps that are iterated in Figure 8.1. This means that the building owner would have go through this process to end with a risk evaluation of the buildings.

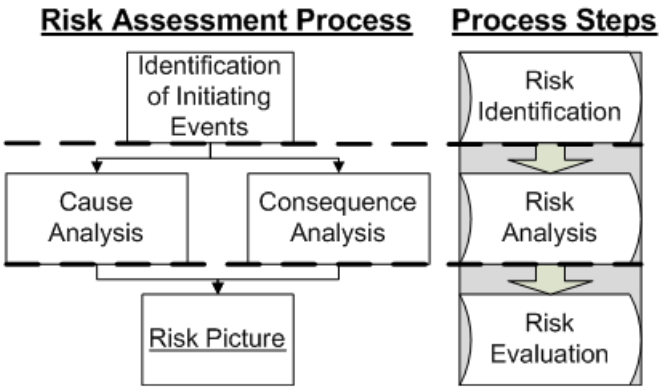

Figure 8.1: The breakdown of the risk assessment process and related steps [32].

It is the intention that the risk assessment process should be carried out in a similar fashion as a HAZID workshop where the purpose is to made a HAZard IDentification. The HAZID workshop methods resemble the HAZard and OPerability (HAZOP) studies, where the characteristics are that a facilitator is used to steer the process [6].

The HAZID goal, which is dependent on the scope, is to identify the given hazards that the business, process, buildings etc. might be exposed to. The HAZID workshop is considered one of the standard risk analysis methods used and can be done with a mix of qualitative and/or quantitative measures [6]. The process is divided into two phases, a preparation phase and a workshop phase which can be seen in Figure 8.2 [67].

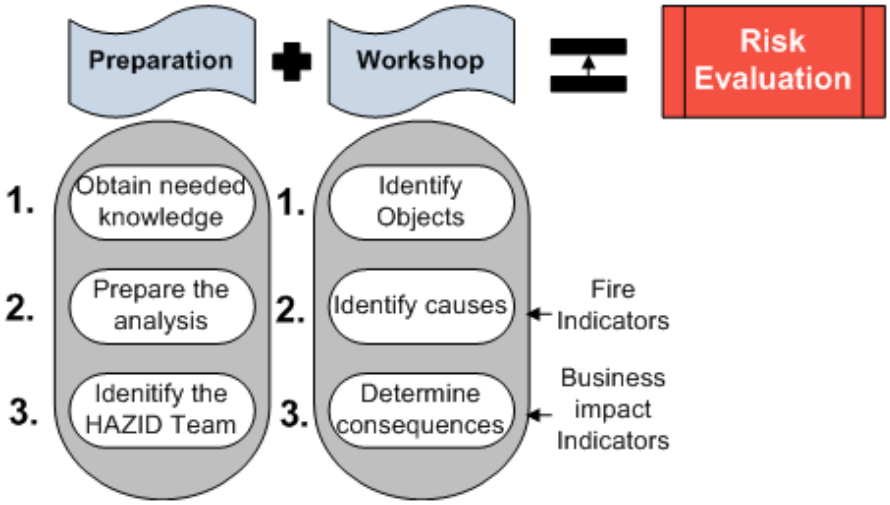

Figure 8.2: The two main phases of the HAZID workshop that lead to an evaluation of the given risks [67].

From the figure it should be understood that prior to the actual workshop it would be needed for the facilitator to obtain relevant knowledge about the indicators and how they should be identified. This highlights that the facilitator would probably be one that has knowledge of how to identify and determine the fire- and business impact indicators. It is also the facilitators responsibility that tools needed for evaluating the risks are prepared and that proper workshop team members are pointed out from the business that is going to be evaluated.

After the evaluation of the buildings has been done, the facilitator can help the client to figure out which buildings he should prioritize based on what the goal of the client is. If it is only to get a preliminary risk picture of the building portfolio to gain oversight, this is where the work of the facilitator ends.

However, if the intention of the client is to work further with the results of the preliminary risk evaluations of the buildings the facilitator should be able to assist the client in prioritizing the buildings based on the clients goals. This ensures that the client has a somewhat impartial opinion of where to commit his resources if the intended action is to mitigate some of the risks found through the preliminary risk evaluation.

This is just a suggestion of how the usage of the indicators could be carried out as to get the most out of them. It could also be possible to implement them into a tool that the client would use himself, without the need of an facilitator, at least for the purpose of filling out the information for the different indicators. A facilitator could then step in when the client

has finished putting in the information about the indicators to facilitate the commitment of resources. The description of how said tool could work is presented in the next section.

8.2 Developing a risk evaluation tool

This section will be concerned about how the indicators could be developed and implemented into a tool. The information about the different indicators would be input and finally give a preliminary risk evaluation of the individual buildings, which can then be compared to each other.

The tool could be developed in various ways depending on how the indicators would be used. The initial intention when the indicators were developed with numerical values, was for them to be used on a graph where one building would be visualized more crucial for the business than another and thereby show a clear difference between buildings. The blank draft of said graph can be seen in Figure 8.3.

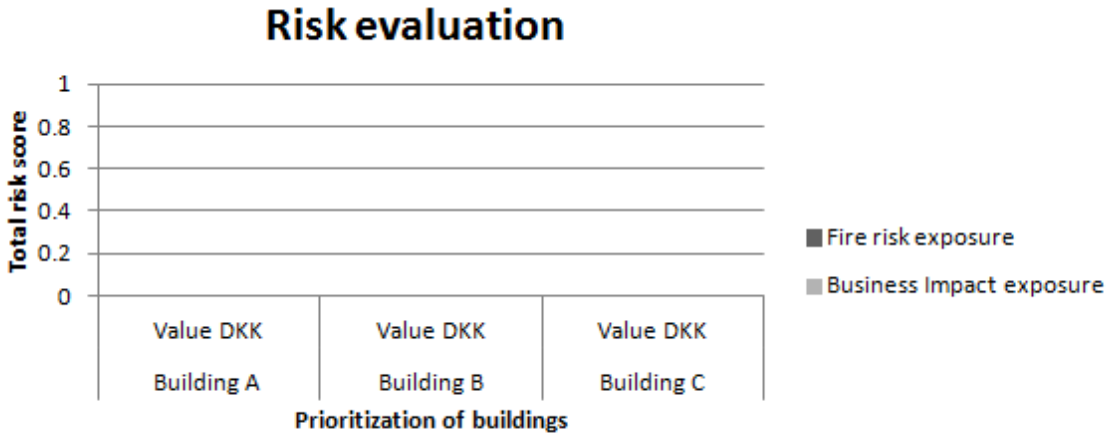

Figure 8.3: The graphs shows the total risk scores for the fire- and business indicators, for the buildings, which is represented by their monetary values.

The initial idea with the graph is not to have any maximum numerical values that determine the highest risk level of a building, which makes it flexible into distinguishing between small differences. According to the interviewees, the prioritization of buildings should be done on the one that indicates the highest monetary loss to the business [APM|Novo Nordisk A/S:01:00-03:20]. For that reason, the value of the buildings represented in the bottom of the graph is in the order of how they would be prioritized due to the monetary value loss they represent.

8.2.1 Case example

Following the HAZID workshop process the first identification that is done is to identify the causes. A sample building has been made to use as an example of a given fictive scenario which is covered in the next section.

8.2.1.1 Fire indicators

A sample building has been made where the following indicators have been identified and is going to be assessed to show how the indicators would be used in a tool.

- The building is located in The capital area
- The building is a school building
- The building is 5.500 m^2
- The building has flammable roof material but not outer wall material
- The building has F-gas installations
- The building is a single story building
- The building rooms that can be assigned a risk score are as follows:

With the given room distribution:

- 2 assembly rooms
- 15 bathrooms
- 8 entrance,hallway
- 1 garbage room
- 6 hallway area
- 2 hobby rooms
- 2 kitchens
- 2 laboratories
- 13 offices
- 1 technical room
- 2 workshops

First of all, the user would select which of the rooms presented in Table 7.6 the building has and the amount of rooms, according to which industry category the building is in. For this particular scenario the building is in the School fires industry category. The selection for the sample scenario can be seen in Table 8.1 with the risk scores for the individual rooms, the amount of each room present in the sample building and the total risk score, which is the risk score multiplied with the amount of the rooms. It is assumed that the risk of a room multiplies when having more than one room of that type, hence the number of rooms is multiplied with the risk score for the single room.

Room type	Risk score	Amount of rooms	Total risk score
Assembly room	0.239	2	0.478
Bathrooms	0.157	15	2.355
Entrance	0.078	8	0.624
Garbage room	0.062	1	0.062
Hallway area	0.098	6	0.588
Hobby rooms	0.078	2	0.156
Kitchens	0.138	2	0.276
Laboratories	0.034	2	0.068
Offices	0.066	13	0.858
Technical room	0.086	1	0.086
Workshop	0.088	2	0.176
Total	**1.124**	**54**	**5.727**

Table 8.1: The risk scores for the different rooms of the sample building including the total risk score for all of the rooms added together.

Here, this is presented as a table, but in the tool this would be a list with rooms where the user would first select what industry category their building is in which in turn would give them a list of rooms to check and calculate the risk score for the individual rooms types in the building and then calculate the total score for rooms and in this case it is 64.87.

Following the assessment of the room types, the next step would be to apply the other indicators that were developed. These are represented in Table 8.2 and are found in a similar way by applying the indicators and the numerical values they were assigned.

These are the last fire indicators that have to be looked at and now it is possible to collect the results from the individual fire indicators to get the total fire risk score for the sample building. This collection of scores can be seen in Table 8.2 which shows the risk scores for the individual fire indicators and the total risk score of the all the fire indicators. This is one way the user could get an overview of the fire indicators and their respective risk scores.

Indicator	Assessment	Risk score
Location	The capital area/ School fires	0.388
Usage	Teaching research etc	2.466
Size	5.500 m^2	0.0423
F-gas installation?	Yes	0.5
Flammable roof material?	Yes	2.241
Flammable wall material?	No	0
More than 1 floors?	No	0
Rooms	-	5.727
Total		**11.364**

Table 8.2: The risk scores for the values of the fire indicators for the sample building excluding the rooms.

From the table it can be read that the information in the value column represents the inputs of the program the user would have to input to get an output of a risk score. The risk score column of the table then represents the outputs of the program based on what inputs are used.

The outputs from the assessment so far, can be seen in a column diagram as is shown in

Figure 8.4 where each fire indicator is represented as a column in the diagram. This might give a better overview of the different indicators and how much they represent out of the total risk score.

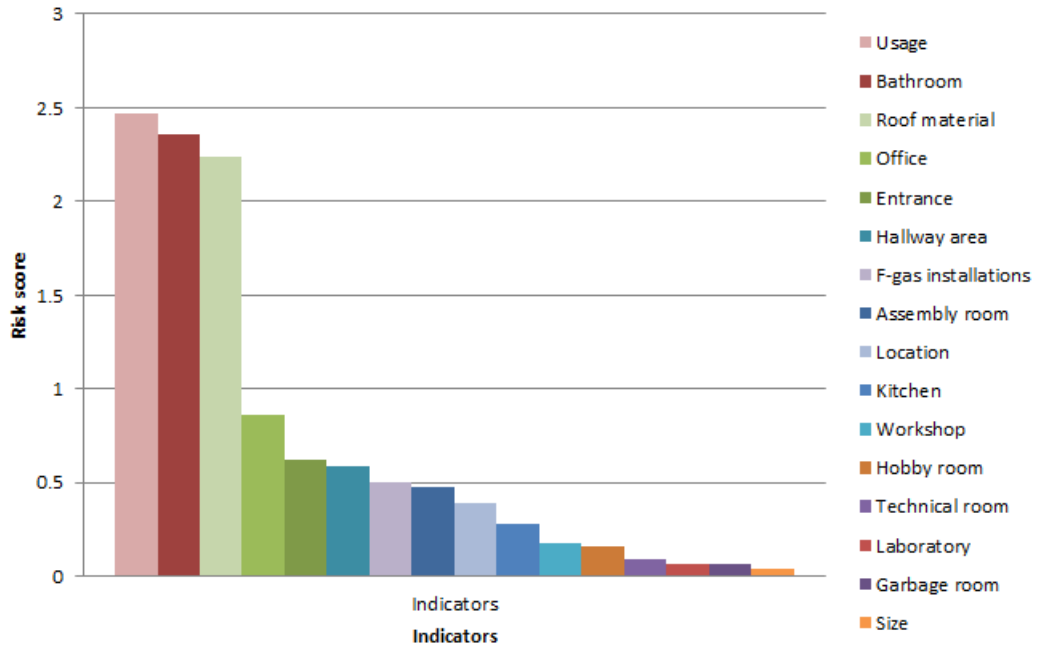

Figure 8.4: The risk scores of the different fire indicators shown as a column diagram.

This concludes the assessment of the fire risk indicators of the sample building. The next step would be to conduct the same assessment for the business impact indicators. Such an assessment, when finalized, could be presented in the same way as was done in Table 8.2.

8.2.1.2 Business impact indicators

For the fictive example school building the following direct indicators have been identified for the schools value, as can be seen in Table 8.3.

Indicators	Assessed values
Physical objects	
1. Physical structure	5.000.000 DKK
2. Other associated structures	50.000 DKK
3. Equipment	100.000 DKK
4. Articles	80.000 DKK
5. Artefacts	50.000 DKK
Total	5.280.000 DKK
Business interruption (BI)	
Time (T)	10 years Approx. 650 days
Quantity (Q)	90 pr. year
Value (V)	10.000 DKK
Time to Resume (TR)	15 days
Capacity (C)	60 pr. year
Additional Expense (AE)	100.000 pr. year
Total loss from BI	13.024.000 DKK

Table 8.3: The table shows the associated monetary values for the physical objects and the values for the business interruption for the example school building.

The challenge with the physical values of the school is to estimate all the values that are encountered in the different underlying parameters as they could have been encountered in the insurance that the school might have. When the values are estimated they are just added together to find the total estimated physical loss of monetary values, which is estimated to be 5.280.000 DKK.

The estimation of the business interruption on the other hand is a little more tricky and it is needed to apply Equation 7.4 from Section 7.5.1. However, before this can be done, the parameter value TR has to be remade to represent the time period of a year which can be seen in Equation 8.1.

$$TR\ in\ years = \frac{15\ Days}{365\ days/year} = 0.04\ years \tag{8.1}$$

Furthermore, it can be seen in the table that AE is made for the period of a year, which has to be represented for the whole time duration T that the building would be inoperable. This gives Equation 8.2.

$$AE = 100.000\ DKK\ pr.year \cdot 10\ years = 1.000.000\ DKK\ pr.\ 10years \tag{8.2}$$

With these terms calculated it is now possible to calculate the business interruption estimate by using Equation 8.3.

$$BI = (T \cdot Q \cdot V - (T - TR) \cdot C \cdot V) + AE \tag{8.3}$$

Equation 8.4 shows the execution of Equation 8.3 with all the values and terms represented.

$$(10\ years \cdot 90\ pr.year \cdot 10.000\ DKK - (10\ years - 0.04\ years) \cdot 60\ pr.year \cdot 10,000\ DKK) + 1.000.000\ DKK = 13.024.000\ DKK \tag{8.4}$$

From Equation 8.4 it can be seen that the estimated business interruptions are calculated to be 13 Million DKK. When put together with the physical losses the total expected loss in monetary values will be approximately 18.3 Million DKK. From this business interruption estimation it can be concluded that the loss of the physical objects only account for approx. 29% of the total monetary loss for the business, which is expected to be a total loss of approx. 18.3 Million DKK over the 10 years.

With the monetary loss estimated it concludes the direct indicators, but the business would also have to identify what possible other effects could make the loss even bigger, if customers, investors, market share etc. were lost because of the event. This is more to estimate without conducting long a complex analysis of how example the reputation would affect the customers to change products.

It would be interesting for the building owner to know it without putting too much effort into it. Then it could be applicable to apply the risk index in Table 7.13 from Section 7.5.2, to evaluate the risk exposure to the compliance, reputational and internal risk impact to the business. The assessment would though best be assessed by the building owners, because it relies on subjective opinion and that person would therefore be the one that knows the most about the business.

For the purpose of showing the whole risk evaluation, a random distribution of the scores of the risk index can be seen in Table 8.4.

	Impact scoring				
Impact indicator questions	**Negligible**	**Minor**	**Moderate**	**Major**	**Sever**
Building function					
1. How important is the building to keep a competitive advantage to attract customers?		X			
2. How important are the building functions in creating better revenues than competitors?			X		
Reputational damage					
3a. To what degree could the loss of a building affect the environment?.			X		
3b. To what degree could the loss of a building affect the social responsibility the business is committed to?			X		
3c. How important is a good environmental and social responsibility reputation to the business?			X		
4a. To what degree could the loss of a building affect the quality of the product?		X			
4b. How important is the product quality for the business to it stakeholders?		X			
5a. To what degree would the loss of the building affect the business to be in compliant with laws and regulations?				X	
5b. How important do the business stakeholders thing this compliance is?		X			
6a. To what degree would the loss of the building affect the business financial performance?			X		
6b. How important is it for the stakeholders that the business performs well?				X	
7a. To what degree would the loss of the building affect the ethics and integrity of the business?					X
7b. How important are ethics and integrity for the stakeholders of the business?					X
Compliance					
8a. To what degree would a failure to deliver affect the business financial compliance?					X
8b. To what degree would a failure to deliver affect the compliance of the business's other operations?					X
8c. To what degree would a compliance failure to deliver, affect the reputation of the business?				X	
8d. To what degree would a failure to deliver affect the legal compliances of the business?				X	
9a.To what degree would a failure to comply with proper quality of products lead to a financial impact?			X		
9b. To what degree would the business flow be impacted by a failure to comply with proper quality?			X		
9c. To what degree would a failure to comply with proper quality of products lead to a reputational impact?		X			
9d. To what degree would a failure to comply with proper quality of products leads to a legal impact?		X			

Table 8.4: Risk index scoring for the School example.

Now this concludes the business impact assessment of the school, where the results are summarized in Table 8.5.

Indicators	**Risk scores**
Direct indicators	
Total value of physical objects	5,280,000 DKK
Total value of business interruption	13,024,000 DKK
Total monetary value sum	**18,340,000**
Indirect indicators	
Total score of the building's function	5
Total score for reputational damage	36
Total score for compliance failure	28
Total indirect indicator score	**69**

Table 8.5: The results for the direct and indirect business impact indicators for the school example.

With the finalized assessment of the school example, the evaluation from it can be presented as was shown in Figure 8.3 that was made earlier in Section 8.2. The results are presented in Figure 8.5 were the evaluation of the school is presented as the most valuable building with a total loss estimation of to be approximately 18.3 million DKK and a risk score for fire exposure to be 11.364 and for business indirect impact on values as 69.

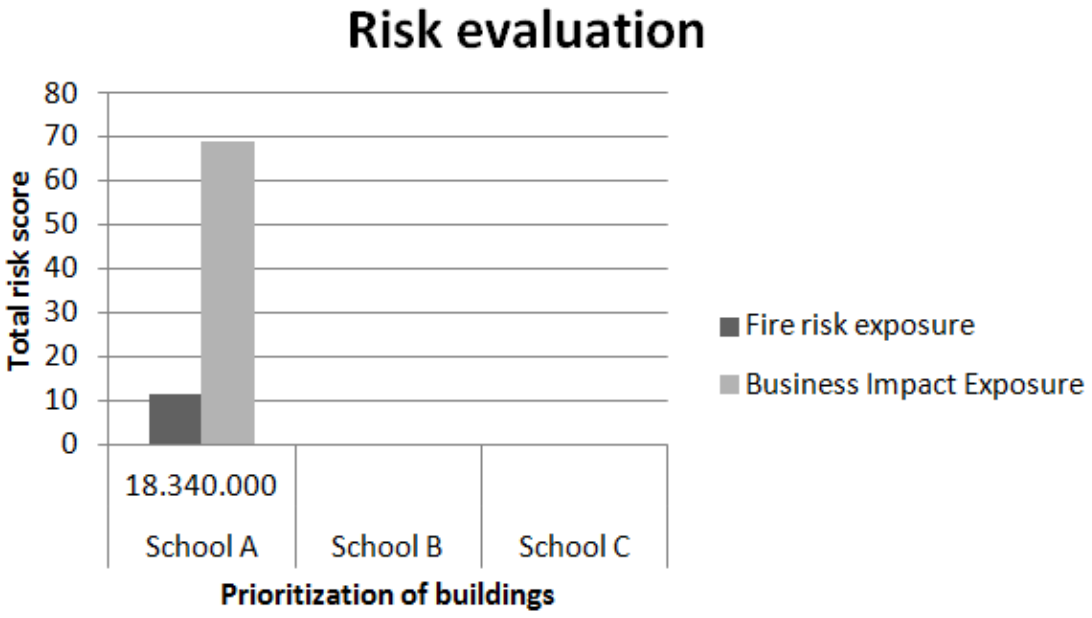

Figure 8.5: Final risk evaluation of the school example.

It is important to note when looking at the evaluation that the fire risk exposure and the business impact exposure are not directly comparable. This is due to that they are not unified in any of their numerical values and neither are measured with same theory. More on comparing prioritized buildings will be explained in the following section.

8.3 Using the results from the risk evaluation

When the HAZID workshop has been finalized there should be made a risk evaluation of the buildings in order for the building owner to prioritize which building that should be focused on when mitigating for fire events. As can be remembered from the risk assessment process, is that the risk evaluation is summed up in a risk picture.

The risk picture is the "message" that presents the results from the risk analysis [6]. Such a presentation can be seen in Figure 8.6 where the example from the previous section is compared in relation to other fictive schools. The figure shows that the previous school example is still the most valuable building in monetary values that building owner has.

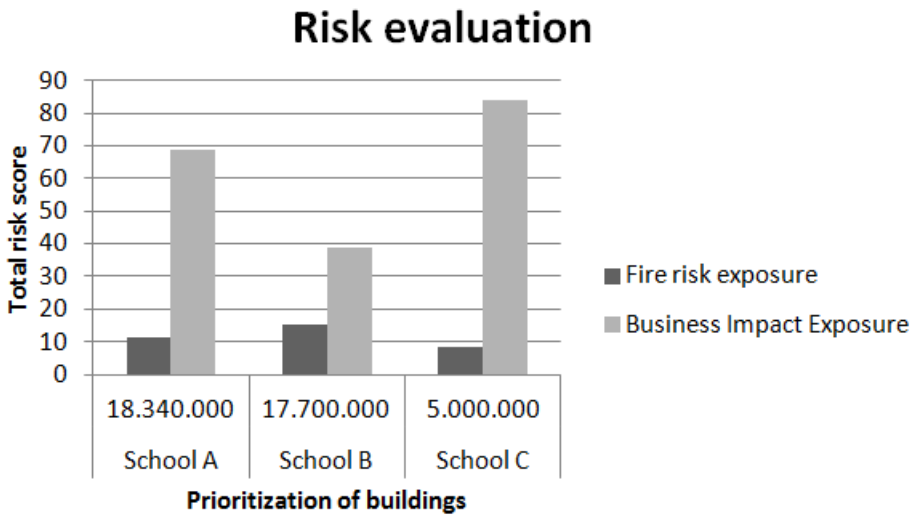

Figure 8.6: A risk picture of a risk evaluation of fire related risks for schools.

With this risk picture of the fire risk evaluation, it should not be possible to determine which building that needs most attention, when it comes to assign time and resources for fire preventive mitigations. The leading factor in choosing which building to start with should be the one where the consequence from a fire event is deemed highest in monetary values. This is due to that monetary values are the reason for why the business exists.

Secondarily, the fire risk exposure of the building should be looked at because this could indicate that risk reduction measures are better invested. From the Example in Figure 8.6 the choice of which building to prioritize would not necessary fall on School A because the loss would be bigger. Instead, it may fall on School B because the loss is very similar but the fire risk score is higher, which could emphasize a better investments.

The business impact exposure is the last variable that should be taken into account, because the impact might not be conclusive since they are subjective and also depends on external perception of the business and the event. The important thing to understand with the business impact exposure, is that it can be an amplifier for the impact to the business and therefore should be accounted for when determining the building that causes the biggest loss.

Chapter 9

Conclusion

When a business consists of a collection of multiple buildings and seeks to address risks of a low frequency with high potential impact, it can be a challenge to determine which building to prioritize both time and resources on. A challenge which in this project has been address with a solution that involves establishing a preliminary risk evaluation to evaluate the individual buildings in comparison to each other and the business. To make said risk evaluation, the solution involved a development of fire related risk indicators to be used as a numerical measurement for both the fire risk and the subsequent impact.

Throughout the project, the main challenge has been to develop the fire related indicators due to a lack in the area with regards to these types of indicators, which lead to the development of a proposed method for developing the fire related indicators, based on some fundamental theories. The method that is used is mainly meant for the purpose of developing indicators in places where non such exist and carries the process through a three stage development phase where the indicators are hypothesized, theoretically concluded and in the end made operational.

The development process resulted in identifying 48 fire indicators of which 21 were through criteria found to be directly related to fire conditions and out of these, seven were theoretically developed and finally five were made reliably operational. The criteria for making the fire indicators to be reliable in an operational context was to make them representative of previously occurred fire event, such that they could point to what previously observed reasons for fires were and what the related severity was. Another criteria was fulfilled by applying statistical evidence which not every of the fire indicators were presented in and therefore could not be developed in the same way.

The second half of the results relates to the potential impact the fire would have on the business if a given building were lost. A total of nine possible indicators were hypothesized, of which five where theoretically concluded and made operational. The result showed a difference between those that could be used to indicate a potential monetary loss to the business and those that could be used to estimate the monetary loss of losing a building to a business.

Following the indicator development it was proposed that the indicators that were made operational could be used in a HAZID workshop, to evaluate a given business's buildings and prioritize them according to their importance. From a risk assessment example it was concluded that the prioritization of buildings should be based on the monetary loss estimation, the fire risk exposure and the business impact exposure in that order. This conclusion was

based on that a business is likely to prioritize the highest monetary loss over any other significant smaller losses. However, that could change if the prioritization is based on where the investment in fire reducing measures would be most beneficial, then it would be the fire exposure.

A discovery was made during the development of the risk scores that some indicators could be used to effect the fire indicators. This discovery is that some of the indicators could be called safety measures as they do not indicate fire risks but point to the use of safety measures. These indicators cover the areas of passive fire protection, active fire protection and procedural based fire protection. The indicators could act as reduction measures towards the risk scores of the buildings in order to make the risk evaluation more precise and take into account that there might be implemented some mitigating safety measures within the building that could contain or minimize the effects of a fire. Using the safety measures as a risk score reduction method would have to be made carefully and possibly so that it does not directly affect the risk scores but could be a score of its own, such that it can be taken into account in the risk evaluation.

To conclude on the results, it can be said that the fire indicators were very small in their numerical values, but what they do in comparison to each other shows a difference between the fire risks of a building. These small numerical values are a representation of that fire occurrence has a low frequency and therefore rarely occur. Further development of the fire indicators could also increase the fire risk values and give a more comprehensive risk evaluation.

What should be taken from this project is that with more substantial statistical data it could be possible to develop additional building risk indicators. This would make the indicators representative of the fire risks that a building is exposed to according to previous events. In order for this to be achievable, the statistics from the fire department would require an update and to gain access to data about fires that have only been reported to insurance companies since they have approximately 76% of the reported fires.

Appendices

Appendix A

Brutto list of indicators

What kind of work leads to fires?

- What is the indicator and the hypothesis of it?

  The indicators is what kind of work leads to fires. The idea is that there is work that can have the potential to start fires. The hypothesis in then that work that includes activities that can start a fire is more riskier to the building than work that does not involve activities that can start a fire.

- Strengths & Weaknesses

  The strengths of this indicator is that it is easy to know what kind of work is being carried out or is allowed to be carried out in the building and makes it easy to identify the difference of the work being carried out. The weaknesses of this indicator is that it is not directly related to the fire triangle as a ignition source or fuel source but is more connected to the human element as it is the person carrying out the work activity that could be the cause for this causing a fire.

- How could it be validated?

  It could be validated by seeing if there is a relationship between different work activities and fires that are said to have started from work activities.

What building materials are most susceptible to fires?

- What is the indicator and the hypothesis of it?

  The indicators is the building materials that the building is built out of such as the outer wall materials and structure materials. The hypothesis is that building materials have different fire properties as to how long they can resist fires, how easily they ignite and they can act as a fuel source.

- Strengths & Weaknesses

  The strengths of this indicator is that it relates directly to one of the parameters in the fire triangle, fuel, as it can act as a fuel source for fires and aid in the spread of fires. As well, it is simple to figure out what materials a building possess. It also offers easy

classification of different materials towards if it is a fuel source. The weaknesses are that there are a lot of materials being used in many different combinations that could make the fire properties hard to evaluate.

- How it could be validated

  This could be validated by use of statistics to research into historical fires to see if some building materials have a higher frequency then other that are causes of fires or spreads of fires.

Laws when the building was built

- What is the indicator and the hypothesis of it?

  The indicator is referring to the building and fire technical(codes) laws that were in use when the building was built. The hypothesis is that through the years building and fire technical(codes) law have become more stricter and advanced than in the past and that might give an indication of safer building that are less likely to catch on fire.

- Strengths & Weaknesses

  The strengths of this indicator is that it is simple to compare the current laws to the laws that have been in regulation in the past to see the difference in the laws. The weaknesses is that this does not related directly into an ignition source or fuel for fires. This indicator can also be reduced in factor if the building in question has in any way been updated to comply with newer laws.

- How it could be validated

  This indicator could be validated by researching into historical fires to see if fires occur more often in buildings that were built when older laws and codes were in use or not.

What makes a company a risky business (Risikovirksomhed)

- What is the indicator and the hypothesis of it?

  This indicators refers to if a building is classified by the Danish laws that regulates especially dangerous buildings. The hypothesis is that the laws for dangerous building that possesses flammable or explosive materials in big quantities can be used to say that those building are more riskier than buildings not classified within these laws.

- Strengths & Weaknesses

  The strengths of this indicator is that it relates directly to the fire triangle as it classifies buildings based on if the have flammable or explosive materials or both by being either a fuel source or the ignition source. It is simple to find out which buildings are classified as the information is readily available from the governmental institution that enforces the law. Furthermore, it has a scaling classification that is based on quantity of the substances, where larger quantities are thought to lead to larger events. The weaknesses of this indicator is that if a building is classified within the laws the confinement of the materials is very strict and the risk might therefore be substantially mitigated. It might also be difficult to prove that having larger quantities of materials makes a bigger

risk. Because that would be relying on that one could make a connection between the quantity of substances with the effect of having a larger quantity

- How it could be validated

  This indicator can be validated by looking into how many fires have occurred in buildings that are classified by the laws, how the fires went and how the substances affected the outcome to see if it actually can give an indication of fires.

What does the legislation do to prove risk?

- What is the indicator and the hypothesis of it?

  This indicators refers to the laws that are in use as of now and what they set forward to be accounted as risk. The hypothesis is that from looking into what the laws require to prove risk one can use those parameters as indicators.

- Strengths & Weaknesses

  The strengths of this indicator is that the laws are easily dissected for the parameters and that since they are in the laws they have to be implemented. The weaknesses is that this does not relate directly to the fire triangle and is more of a regulatory risk that could be hard to evaluate.

- How it could be validated

  This indicator could be validated by comparing the risk parameters of the laws to fires to see if they give any indication of fire events.

What do standards do to prove risk?

- What is the indicator and the hypothesis of it?

  This indicator refers to the standards that are used today and what they set forward to be accounted as risk. The hypothesis is that from looking into what the standards require to prove risk could be used as indicators.

- Strengths & Weaknesses

  The strength of this indicators is that the standards are easy to dissect for the parameters and to know if they are being implemented. The weakness of this indicator is that it does not directly relate to the fire triangle and is more of a regulatory risk that could be hard to evaluate.

- How it could be validated

  This indicator could be validated by comparing the risk parameters of the standards to fires to see if they give any indication of fire events.

Maintenance of equipment in the building

- What is the indicator and the hypothesis of it?

  This indicator refers to how the maintenance of the equipment that is located inside the building can affect the equipment. The hypothesis is that lack of maintenance on equipment, especially on large equipment that has moving parts can lead to the equipment breaking down and potentially cause fires.

- Strengths & Weaknesses

  The strengths of this indicators is that it can be related to the fire triangle as moving parts in machines can create friction that can turn into a ignition source for fires and then the equipment itself can be a fuel source for fires. The weakness of this indicators is that it might be difficult to estimate how much maintenance reduces the likelihood of it catching on fire and if it has an affect at all.

- How it could be validated

  This indicator could be validated by looking into maintenance management and researching into how maintenance plans reduce the likelihood of breakdowns that can lead to fires. And then this could tell the difference of doing maintenance versus not.

Maintenance of the building

- What is the indicator and the hypothesis of it?

  This indicators refers to the maintenance of a building and how it could affect the status of the building. The hypotheses is that doing maintenance on the building reduces the risk of fire events versus not doing maintenance and might make the building more susceptible to fires.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to know if maintenance is being carried out as well as that it can be related to the fire triangle as a fuel source. The weakness of this indicators is that it is hard to quantify the effect of maintenance on a building and what is enough to not compromise the building.

- How it could be validated

  This indicator could be validated by looking into maintenance management and researching into how maintenance plans have an effect on the buildings overall status. And then this could tell the difference of doing maintenance versus not.

Are some products more riskier to produce than other?

- What is the indicator and the hypothesis of it?

  The indicator is the product that a company might be producing and if producing some products entails more risk than others. The hypothesis is that some products are more

riskier to produce than other as they might need flammable or explosive materials in the production phase or the end product itself is dangerous.

- Strengths & Weaknesses

  The strength for this indicator is that it relates directly to the fire triangle as products can be fuel for fires and the source for fires starting. The weakness of this indicator is that there are so many products that are being produces that it might be difficult to get an overview of all the elements that go into making products.

- How it could be validated

  This indicator can be validated by researching into what products are dangerous as end products and which products use flammable or explosive materials in the production process and compare to the fires they have caused.

Are there open flames in the building?

- What is the indicator and the hypothesis of it?

  This indicator is about if there are some open flames like candles or fire places in the building. The hypothesis is that if open flames like candles and fire places are allowed in the building that can give an indication that fires occur.

- Strengths & Weaknesses

  The strength of this indicators is that it directly relates to the fire triangle as open flames are ignition sources for fires. The weakness is that it can be difficult to know if this is allowed or not in a building and to quantify how the risk might increase with the sue of more than one candle or fire place.

- How it could be validated

  This indicator could be validated by seeing if there is a relation between causes of fires and the allowance of open flames in the buildings that have caught on fire.

Is reconstruction/renovations/additions a sign of fire risk?

- What is the indicator and the hypothesis of it?

  This indicator refers to if the building has been renovated/reconstructed or had additions added on to it. The hypothesis is that if one or more of these things have been done to a building they might make the building vulnerable as these things change the original design of the building and may leave work that has not been done properly.

- Strengths & Weaknesses

  The strength of this indicator is that it is simple to find information if there have been done any reconstructions/renovation or additions. The weakness of this indicator is that it is not directly related to the fire triangle as an ignition source or fuel as well as it is hard to measure the difference in different levels of reconstructions/renovations and additions.

- How it could be validated

  This indicator could be validated by investigating how many fires have been directly linked with reconstruction/renovations and additions to see if they indicate fire.

Electrical equipment

- What is the indicator and the hypothesis of it?

  This indicator refers to electrical equipment that is inside the building. The hypothesis is that electrical equipment use electricity and have been linked to be the cause of many fires. It can be household equipment, electrical lines and such.

- Strengths & Weaknesses

  The strength for this indicator is that it is directly related to the fire triangle as an ignition source and it is fairly easy to know what kind of electrical equipment is being used inside the building. The weakness is that not all electrical equipment is the same and some pose more risk than others.

- How it could be validated

  This indicator could be validated by looking at statistical evidence for causes of fires to see which electrical equipment causes the most fires and use those as indicators.

Heating/heating medium

- What is the indicator and the hypothesis of it?

  This indicators refers to the heating type and heating medium type that a building uses as a heat source. The hypothesis is that heating generates heat that be the source of fires and then if a heating medium is used that can act as a fuel source for fires.

- Strengths & Weaknesses

  The strength for this indicator is that it directly relates to the fire triangle as a heat source and ignition source and it is fairly easy to identify which system is being used in a building as it is required to register in the BBR. The weakness for this indicator is that there might be used combinations of heating systems that could be difficult to evaluate the effect of.

- How it could be validated

  This indicator could be validated by using statistics to see how often the heating or heating medium has been a cause or a contributing factor to a fire and see if it can be used as an indicator.

Lack of insurance inspection

- What is the indicator and the hypothesis of it?

This indicator refers to insurance inspections and the use of them. The hypothesis is that if there is a long time since an insurance inspection has been done the overall fire safety of the building might be lacking as insurance companies point out vulnerable parts in their inspections.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to find out when the last inspection was made and see what was recommended to do then. The weakness for this indicator is that it does not directly relate to the fire triangle and that it is based on the insurance companies opinion.

- How it could be validated

  This indicator could be validated by looking at historical fires and compare when those buildings last had an insurance inspection to see if this is an indicator.

Roof material

- What is the indicator and the hypothesis of it?

  This indicator refers to the materials that are used in the roof. The hypothesis is that there are used many different materials for roofing that have different fire properties as to how long they can resist fires, how easily they ignite and that they can act as a fuel source.

- Strengths & Weaknesses

  The strengths of this indicator is that it relates directly to one of the parameters in the fire triangle, fuel, as it can act as a fuel source for fires and aid in the spread of fires. As well, it is simple to figure out what materials a building possess. It also offers easy classification of different materials towards if it is a fuel source. The weaknesses are that there are a lot of materials being used in many different combinations that could make the fire properties hard to evaluate.

- How it could be validated

  This could be validated by use of statistics to research into historical fires to see if some roof materials have a higher frequency then other that are causes of fires or spreads of fires

Is there work in the building 24/7?

- What is the indicator and the hypothesis of it?

  This indicator refers to the work that is carried out in the building and how much the building is used. The hypothesis is that the more time personnel is present in the building it translates in to more risk as the building is being used a lot. However, having people present all the time might also reduce the risk as there is then alwasy someone to react to a fire if it were to occur.

- Strengths & Weaknesses

  The strength for this indicator is that it is simple to find out if the building is being used for work 24/7 or not as well as it could be related to the fire triangle if the work being done involves activities that can cause or escalate fires. The weakness for this indicator is that it is not directly related to the fire triangle as a fuel source or ignition source and that it can be considered to be somewhat of a safety measure as well.

- How it could be validated

  This indicator could be validated by looking into building fires and the relationship to the amount of work that was done in the buildings to see if this is an indicator.

Distance to the fire department

- What is the indicator and the hypothesis of it?

  This indicator refers to the distance from the building to the fire department. The hypothesis is that buildings that are far away from the fire department are more likely to have severe fires as it would take the fire department longer to get to them than if the building was located closer. Also it could be that buildings that are very close to the fire department tend to ignore fire safety and feel more safer than they should be because they are so close to the fire department.

- Strengths & Weaknesses

  The strength of this indicator is that it is simple to figure out the distance from the fire department and the potential response time. The weakness of this indicator is that it is not directly related to the fire triangle as an ignition source or fuel source and that it is based on human elements and thoughts.

- How it could be validated

  It could be validated by seeing if there are more fires occurring the further the building is located from the fire department to see if this indicates that.

Are the neighbouring buildings dangerous?

- What is the indicator and the hypothesis of it?

  This indicator refers to the neighbouring buildings around the building being evaluated. The hypothesis is that the neighbouring buildings might contain some dangerous goods that are flammable or explosive and when lit can spread to other buildings.

- Strengths & Weaknesses

  The strength of this indicator is that it relates directly to the fire triangle as the neighbouring buildings can act as a fuel source or an ignition source and spread to other buildings. The weakness for this indicator is that it could be difficult to get detailed information about the neighbouring buildings in order to determine if the pose a risk.

- How it could be validated

  This indicator can be validated by looking into how many fires have been directly caused by that a neighbouring building has caught on fire and fire spreading into nearby buildings.

Electrical installations

- What is the indicator and the hypothesis of it?

  This indicator refers to the electrical installations that a building might have. The hypothesis is that electrical installations such as solar panels, transformers and such can cause fires by malfunctioning or breaking down and creating a fire source.

- Strengths & Weaknesses

  The strength of this indicator is that it relates directly to the fire triangle as an ignition source and potentially as a fuel source. The weakness for this indicator is that there are so many different electrical installations that it would be difficult to evaluate the effect of them.

- How it could be validated

  This indicator could be validated by looking into how many fires have been started by electrical equipment versus other causes to see if this is actually an indicator.

Household equipment

- What is the indicator and the hypothesis of it?

  This indicator refers to the household equipment that might be inside the building. The hypothesis is that household equipment such as coffee machines, stoves, kettles and such can cause fires if not properly used.

- Strengths & Weaknesses

  The strength for this indicator is that it relates directly to the fire triangle as a fuel source and ignition source as well as it being well documented that household equipment is known to cause fires when not properly used. The weakness for this indicator is that in order to know if any household equipment is in use in the building it most likely has to be inspected and can not be known 100% from the office.

- How it could be validated

  This indicator could be validated by looking at statistics for what kind of household equipment is most often the cause for fires and use them as indicators.

Usage of the building

- What is the indicator and the hypothesis of it?

This indicator refers to what the building is being used for. The hypothesis is that different usages of building pose different risk such as a dynamite factory poses a larger risk to fire than a office building.

- Strengths & Weaknesses

  The strengths for this indicator is that the usage of the building is very easy to figure out and that some usage of buildings could be directly related to the fire triangle as ignition sources or fuel sources. The weakness of this indicator is that a building could be designed for something else than that it is currently being used for and that might not give an accurate picture.

- How it could be validated

  This indicator could be validated by exploring historical fires and look into what the usage was of the buildings that caught on fire to see if this could be used as an indicator.

Size of the building

- What is the indicator and the hypothesis of it?

  This indicator refers to the size of the building. The hypothesis is that the bigger a building is the more likely it is to have fires.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to find the size of the building and that it could tell about expected number of fires for a building. The weakness for this indicator is that it only focuses on size and does not take into account what the building is used for.

- How it could be validated

  This indicator can be validated by looking at fires versus the size of the building they occurred in to get see if fires really do occur more often in bigger buildings or not.

Especially risky rooms

- What is the indicator and the hypothesis of it?

  This indicator refers to the rooms of the building. The hypothesis is that some rooms in a building pose a larger risk then other due the the content and/or the usage/activities being carried out in the room.

- Strengths & Weaknesses

  The strength of this indicator is that the usage, content and the activities carried out in a room can be established relatively easily. As well some rooms could be directly related to the fire triangle as fuel sources and potentially ignition sources. The weakness for this indicator is that the room is possibly not being used for what it was originally intended to be used for and that might throw the indicators off and make the estimation skewed.

- How it could be validated

  This indicator can be validated by looking into what rooms fires have started in the past and use that as an indicator for future occurrences.

Location

- What is the indicator and the hypothesis of it?

  This indicator refers to the location of the building. The hypothesis is that external factors based on the location of the building can be regarded as risks such as vandalism, arsons, robberies and weather.

- Strengths & Weaknesses

  The strength for this indicator is that it is easy to determine the location of a building and if location is a factor. The weakness for this indicator can be that it is to wide and covers to big of an area such that if the buildings are all in the same relative location there might not be any difference.

- How it could be validated

  This indicator could be validated by seeing how fires are distributed over locations (regions) in Denmark to see if this can be used as an indicator.

Number of floors

- What is the indicator and the hypothesis of it?

  This indicator refers to the number of floors(storeys) that a building has. The hypothesis is that the more floors a building has the riskier it is. The more floors a building has the size of it also increases and is therefore somewhat related to that indicator.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to figure out how many floors a building has. The weakness for this indicator is that it might be the same ans the size of the building and the possibility of the number of floors not being a factor.

- How it could be validated

  This indicator can be validated by looking into fires in multi storey buildings to see if there is a trend to them catching on fire that can be used as an indicator.

Fire technical installations

- What is the indicator and the hypothesis of it?

  This indicator refers to the fire technical installations that are installed in the building. The hypothesis is that the more fire technical installations a building has the less likely it is to have fires of large severity.

- Strengths & Weaknesses

  The strength of this indicator is that most buildings have at least some fire technical installations and it should be fairly simple to figure out how much they have. The weakness for this indicator is that it might be more of a safety measure indicator than fire indicator as the function of fire technical installations is to mitigate the fire that has already occurred.

- How it could be validated

  This indicator could be validated by looking at how much different fire technical installation effect fire and how the different installations help reduce the size of fire.

What is the age of the building?

- What is the indicator and the hypothesis of it?

  This indicator refers to the physical age of a building, i.e when it was first built. The hypothesis is that the older a building is the more likely it is to have a fire occurring.

- Strengths & Weaknesses

  The strength of this indicator is that it is very simple to determine the age of a building. The weaknesses of this indicator are that there are so many things that can mitigate the effect the age of building and render it relatively useless. If the building has been renovated, reconstructed or additions added to it the building could have been brought up to the newest laws and codes and with a proper maintenance plan the age of the building can be mitigated as well.

- How it could be validated

  This indicator could be validated by looking into historical fires and looking at the age of the buildings that caught on fire to see if older building really do pose a larger risk than newer buildings.

Installations that use gas

- What is the indicator and the hypothesis of it?

  This indicator refers to installations in the buildings that use gas. The hypothesis is that in some buildings there might be some installations that use gas such as stoves, laboratories, oxygen systems for patients and furnaces.

- Strengths & Weaknesses

  The strength of this indicator is that it relates directly to the fire triangle as the gas can both be a cause of fire and and ignition source. Furthermore, it should be relatively easy to figure out if there are any installations that use gas in the building. The weakness is that for a gas to be a danger it has to have the right mixture to air to cause fires.

- How it could be validated

This could be evaluated by looking at how many fires are caused by gasses and relate that to buildings that have gas installations to see if this is an indicator.

Maintenance plans

- What is the indicator and the hypothesis of it?

  This indicator refers to maintenance plans. The hypothesis is that if there are no maintenance plans in use for the building, the equipment or the general elements in the building then that will pose a higher fire risk than if there are plans in use.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to know if there are maintenance plans. The weaknesses are that it even though there is a maintenance plan it is not sure if they are being followed and that this relies on human factor to be implemented.

- How it could be validated

  This indicator could be validated by looking into maintenance management and researching into how maintenance plans have an effect on the buildings overall status. And then this could tell the difference of doing maintenance versus not.

Flammable storage

- What is the indicator and the hypothesis of it?

  This indicator refers to if the building has storage materials that are flammable. The hypothesis is that having a storage that contains flammable materials is a risk as the material can be considered as a fuel source.

- Strengths & Weaknesses

  The strength of this indicator is that it directly relates to the fire triangle as a fuel source for fires and it is relatively easy to know if a building is storing flammable materials. The weakness of this indicator is that usually flammable materials are stored in very fire secured rooms and might therefore not pose as big of a risk as thought.

- How it could be validated

  This indicator could be validated by looking into what specific material are flammable and if they have been the cause or escalation of fire to see if this can be used as an indicator.

Construction classification U/BS/BD

- What is the indicator and the hypothesis of it?

  This indicator refers to the construction classification of the material used inside the building. The hypothesis is that the more construction material that is used that has the best classification the less fire spread there will be.

- Strengths & Weaknesses

  The strength of this indicator is that it should be easy to find the information of what classification material was used in the building. The weakness for this indicator is that it is more of a safety measure as its purpose it to minimize the spread of the fire and contain it.

- How it could be validated

  This indicator could be validated by looking at how the different classifications deal with fires and use that as an indication for safety measures.

Fire separation parts classification

- What is the indicator and the hypothesis of it?

  This indicators refers to how the fire separation has been done within the building. The hypothesis is that if the fire separation has the highest quality classification it can give an indication of the building being safer than if it had lower quality classification.

- Strengths & Weaknesses

  The strength for this indicator is that the information about the fire separation parts classifications should be fairly easy to acquire. The weakness for this indicator is that there are a lot of separation parts within a single building and might be difficult to contain and sort all the information.

- How it could be validated

  This indicator could be validated by looking into how the fire separation classifications have been in past fires to see if there is any positive or negative affect of having them.

Protected or conserved building

- What is the indicator and the hypothesis of it?

  This indicator refers to if the building is protected or conserved under laws. The hypothesis is that if a building is preserved or protected by the law that the building might be more vulnerable to fires due to that the buildings features have to be kept up as to how the building was first built.

- Strengths & Weaknesses

  The strength of this indicator is that information about preserved or protected building is easily obtainable and the weakness is that the state of the preserved or protected buildings might vary so much that this might not give an accurate indication.

- How it could be validated

  This indicator could be validated by looking into past fires and seeing how many buildings have had fires that are protected or preserved to see if this can be used as an indicator.

Fire segregation

- What is the indicator and the hypothesis of it?

  This indicator refers to the fire segregation of a building. The hypothesis is that the more fire segregation there if the safer the building is and the less likely it is that the fire evolves to a large fire before it can be contained.

- Strengths & Weaknesses

  The strength for this indicator is that the information about the fire segregation can be read directly from the building schematics and is therefore easily obtainable information. The weakness is that fire segregations have many different sizes and buildings have different amounts of fire segregations present and it might be difficult to estimate the effect of them.

- How it could be validated

  This indicator could be validated by linking fire segregation to fires that have occurred to see how and if the fire segregation did have an impact on the fire and that could be used to determine if this could be used as an indicator, either a fire indicator or as a safety measure.

Insurance level

- What is the indicator and the hypothesis of it?

  This indicator refers to the insurance level of the building. The hypothesis is that the better insurance level a building has, the less vulnerable to fire it might be.

- Strengths & Weaknesses

  The strength of this indicator is that the information about the insurance level of the building is easily obtained from the insurer and that changes in the insurance level for a building should be easily obtained as well. The weakness for this indicator is that the insurance level might not be connected to how vulnerable the building is for fires.

- How it could be validated

  This indicator could be validated by looking into historical fires and research the insurance levels of the buildings involved in these fires to see if the insurance level has an affect on the vulnerability of building towards fires.

Management (Global/local/central)

- What is the indicator and the hypothesis of it?

  This indicator refers to how the management level of the building is. The hypothesis is that the closer the management is to the building the better control of the building and its functions the company has.

- Strengths & Weaknesses

  The strength for this indicator is that the management level of a building should be fairly easy to determine. The weakness of this indicator is that the management levels could be so different between building from building that it might be difficult to make a stable indicator from it.

- How it could be validated

  This indicator could be validated by looking at the management levels of buildings that have already caught on fire to see if there is any consernable trend that can be used into an indicator.

Human behaviour

- What is the indicator and the hypothesis of it?

  This indicator refers to human behaviour. The hypothesis is that the human behaviour within a building could give an indication of if the people in the building follow rules or comply with SOPs and such.

- Strengths & Weaknesses

  The strengths for this indicator is that it could be related to the safety culture within the building to measure the human behaviour. The weakness for this indicator is that measuring human behaviour is extremely difficult and comparing it to the human behaviour in another building might be even more difficult.

- How it could be validated

  This indicator could be validated by looking into historical fires and researching to see if there is any correlation between the fires and how the human behaviour was within the building.

Standard operation procedure for hot work

- What is the indicator and the hypothesis of it?

  This indicator refer to if there is a standard operating procedure (SOP) for how work. The hypothesis is that where hot work(welding,grinding, cutting) is being done there is a fire risk. Then if there is an SOP in place that will reduce the risk incorporated in these activities.

- Strengths & Weaknesses

  The strength for this indicator is that it is easy to find out if there is an SOP in place for hot work as well as it directly relating to the fire triangle as an ignition source. The weaknesses for this indicator is that even though there is an SOP in place that is no guarantee that it is being followed and it might be difficult to evaluate the impact of having an SOP versus not having it.

- How it could be validated

  This indicator could be validated by looking at how many fires have been started by hot work and then determining how many of those fire instances had implemented an SOP.

Company rules

- What is the indicator and the hypothesis of it?

  This indicator refers to if a company has company wide rules that all employees have to follow. The hypothesis is that if the company has company wide rules and all the employees follow them it might make the building safer from fires than if they were not implemented or not followed.

- Strengths & Weaknesses

  The strength of this indicator is that it is fairly easy to know if a company has company rules. The weakness for this indicator is that even though rules are in place, they might not be followed by the personnel and thus giving a false sense of security.

- How it could be validated

  This indicator could be validated by looking into historical fires and research into if any of those building that caught on fire had implemented company rules and if they were actually follow to see if this can be used as an indicator.

Working environment's smiley's

- What is the indicator and the hypothesis of it?

  This indicator refers to the smiley system that the working environment authority gives to companies. The hypothesis is that if the working environment has a bad grade in the smiley system that might relate to the employees attitude and imply that they don't care that much or are frustrated with the working environment.

- Strengths & Weaknesses

  The strength for this indicator is that it is simple to find out the smiley score from the working environment authority. The weakness is that it is difficult to say how it can relate to fires.

- How it could be validated

  This indicator could be validated by looking into if there is a relationship between fire occurrences and the grade of smiley from the working environment authority.

Number of work injuries/accidents

- What is the indicator and the hypothesis of it?

This indicator refers to the number of work injuries or accidents the work place has. The hypothesis is that the more workplace injuries or accidents there are the worse the state of the workplace is and it could be littered with danger for the employees, This could translate into more fire risks.

- Strengths & Weaknesses

  The strength of this indicator is that it is easy to find out the number of work injuries or accidents. The weakness is that it is related to human elements and it might be that work injuries and accidents don't directly translate into an increase risk of fires occurring.

- How it could be validated

  This indicator could be validated by relating the number of fires to the number of workplace injuries or accidents to see if t-it is an indication of increased fire risk.

Thermography of electrical circuits/components

- What is the indicator and the hypothesis of it?

  This indicator refers to the act thermographing the electrical circuits or components. The hypothesis is that the more frequently this act is done the more likely one is to catch a possible failure in the electrical systems or components.

- Strengths & Weaknesses

  The strength for this indicator is that it can be easily found out how many thermographys have been done in a building. The weakness for this indicator is that it might be more of a safety measure than fire indicators

- How it could be validated

  This indicator could be validated by relating the number of fires to how many thermographys have been done in the buildings that caught on fire to see if there is a relationship between them.

Weather factors

- What is the indicator and the hypothesis of it?

  This indicators refers to weather factors that could affect a building. The hypothesis is that some weather factors can affect the building in a negative way and thus cause fires such as lightnings.

- Strengths & Weaknesses

  The strength of this indicator is that it can be directly related to the fire triangle as an ignition source and that weather data is easily available. The weakness for this indicator is that it might not be that big of a a factor involving fires.

- How it could be validated

This indicator could be validated by looking at how many fires have been started by weather factors to see if there is any indication that can be used.

Production equipment (large machines)

- What is the indicator and the hypothesis of it?

  This indicator refers to large production equipment such as production lines. The hypothesis is that having large production equipment inside the building increases the risk of the building due to the equipment and its potential to start fires and be a fuel source for fires.

- Strengths & Weaknesses

  The strengths of this indicator is that it directly relates to the fire triangle as an ignition source or a fuel source and it can be easily determined the amount of production equipment in a building. The weakness for this indicator is that there are so many different types of equipment that it might be difficult to evaluate the different effects they have.

- How it could be validated

  This indicator can be validated by looking into how many fires have been started or escalated by large production equipment to see if there is any indication of fires.

Is smoking allowed in or around the building?

- What is the indicator and the hypothesis of it?

  This indicator refers to smoking in or around the building. The hypothesis is that if smoking is allowed in or near the building it poses a fire risk as cigarettes can be considered to be an ignition source.

- Strengths & Weaknesses

  The strength of this indicator is that it relates directly to the fire triangle as an ignition source and it is widely known that cigarettes are causes for fires. The weakness of this indicator is that there are laws regarding smoking in and around buildings and if it is allowed it will be in specially designed areas that might mitigate this affect.

- How it could be validated

  This indicator could be validated by looking into how many fires have been started by smoking to see if this is an indication.

Flammable chemicals/liquids/gasses

- What is the indicator and the hypothesis of it?

  This indicator refers to flammable chemicals, liquids or gasses that might be inside of the building. The hypothesis is that if there are flammable chemicals, liquids or gasses

inside the building that will increase the threat level as they pose a direct danger to the building due to their flammable properties.

- Strengths & Weaknesses

  The strength for this indicator is that it is directly related to the fire triangle as both an ignition source and fuel for fires to escalate. The weakness for this indicator is that if any of these elements are present in the building they will most likely be kept in very secure locations specially designed to store them that might mitigate the risk of them.

- How it could be validated

  This indicator can be validated by looking into fires and seeing where these elements have been a contribution factor or the starting factor for fires.

Is there a sprinkler system?

- What is the indicator and the hypothesis of it?

  This indicator refers to if the building has a sprinkler system installed or not. The hypothesis is that if a building is equipped with a sprinkler system it will help to minimize the effect of a fire event.

- Strengths & Weaknesses

  The strength of this indicator is that it can easily be found out how much of the building has sprinklers. The weakness for this indicator is that it is more of a safety measure as it deals with a fire after it has started and thus has the possibility to minimize the effect of an fire.

- How it could be validated

  This indicator could be validated by looking into how much having a sprinkler system reduces the size of fires to see if it indicates that.

Vandalism

- What is the indicator and the hypothesis of it?

  This indicator refers to vandalism to the building. The hypothesis is that vandalism can be the cause of fires and pose a risk towards a building.

- Strengths & Weaknesses

  The strength for this indicator is that it is easy to find out if vandalism is being done and how much it poses a risk, it can also be directly related to the fire triangle as a possible ignition source. The weakness for this indicator is that it is likely to differ greatly between areas in the country and therefore would have to be developed for small areas at a time.

- How it could be validated

  This indicator could be validated by looking into how many fires have been started by vandalism to see if this is an indication.

Appendix B

BRS databank

The indicators that were selected were all collected data on. This was done by using the statistical database operated by the Danish Emergency Management Agency (Beredskapsstyrelsen (DEMA)) which is called the Municipal fire and rescue services database (Redningsberedskabets Statistikbank) and has information and data about 10 different fire and rescue categories, one of which is about fires [43].

The fire category which is the most interesting for this project, is further subdivided into seven categories, which are:

- Location of fire (Brandplacering)
- The object that ignited the fire (Brandobjekt)
- Suspected cause of fire (Formodet brandårsag)
- Fire classification Brandklassificering
- Building fire (Bygningsbrand)
- The room where the fire started (Rum hvor branden startede)
- Situation on arrival (Situation ved ankomst)

Furthermore, the data in these categories can be manipulated by the use of several event categorises, of which the following are used in this project:

- Region

  Can be used to categorize fires after which of the five regions in Denmark they occurred.

- Fire type (Brandtype)

  Shows either fires that occurred in buildings or other areas.

- Placement of the fires (Brandplacering kategori)

  The fires can be classified into residential, business, open areas or unsolved as to where they occurred.

- Fire classification (Brandklassificering)

  Shows the classification of fires by the sizes of the fires.

- Metric (Metrik)

  Shows the data as absolute number, percentage or per 10.000 residents.

- The object that ignited the fire grouped (Brandobjekt gruppe)

  Shows the fires classified into 23 subcategories after what objects ignited the fire.

The database offers data from fire departments from all over Denmark and it offers data from 2007 until 2015, with registration of events for 2015 not finished. The database offers a simple and an easy way to gather data for possible indicators for development. The database gives the potential to use data and/or statistical trends as indicators for Denmark.

Appendix C

Interview research

In this appendix it is the purpose to elaborate on the qualitative interview research method used to identify FIs and BIIs for buildings and business. It is the purpose it is the purpose with this appendix to describe the interview in its seven phases, in order to obtain useful knowledge about said indicators.

Applied Interview method

The first thing to know about interviews is that they according to Brinkmann and Kvale are carried through seven phases [68]. With the knowledge of these seven phases it becomes easier to understand the interview, and thereby also enable a planning of the interviews, to ensure most valuable results. In Figure C.1 is a picture of the interviews seven phases with definition of what they encompasses.

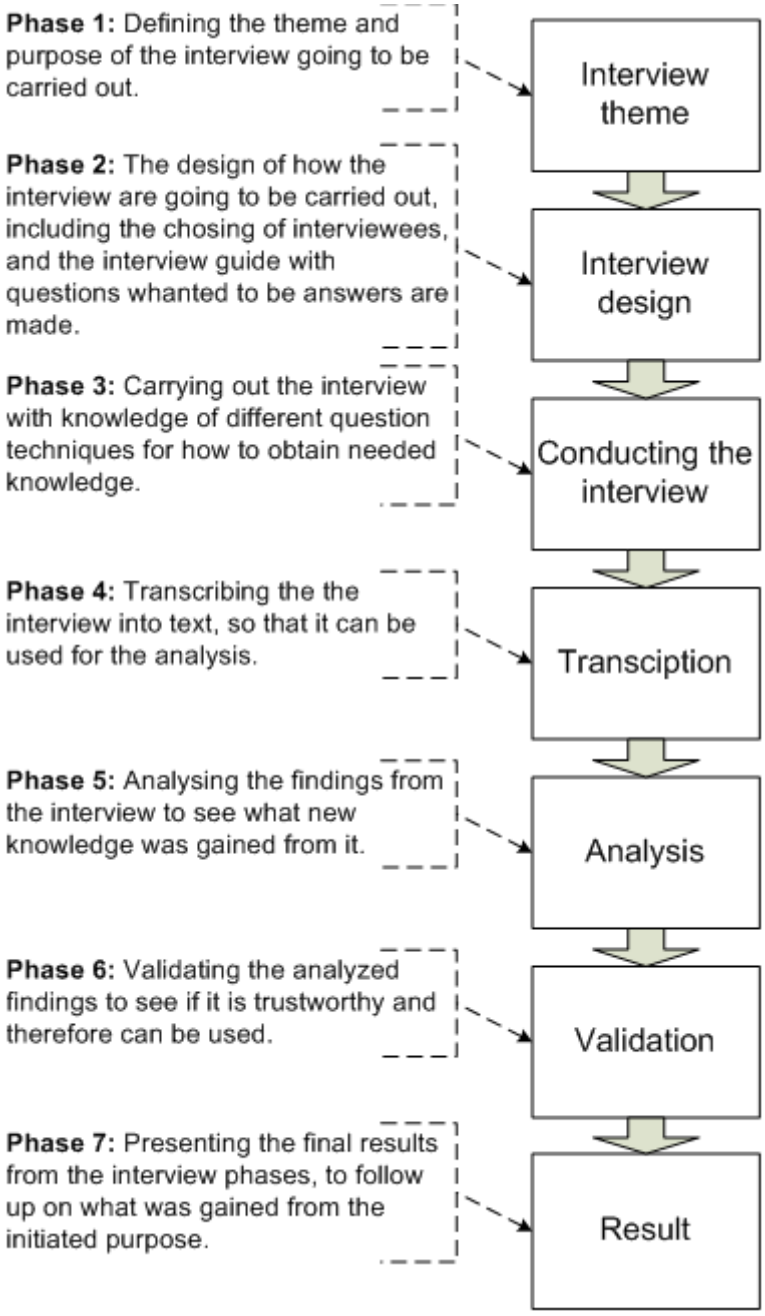

Figure C.1: These are the Seven phases that a interview are made up from [68].

Now that the interviews seven phases has been broadly defined, the next would be to dig into how these seven phases are used in this particular project. This however will be carried out in the following sections, where also results from the interview will be explained.

Interview Theme

Now the first phase of the qualitative interview is about setting the theme and thereby also the purpose for the interview. This initiating state in important to be defined, because it is what is suppose to carry the interviewer through the whole interview process towards the

specific goal [68]. As mentioned in Chapter 3 the main purpose for using interview is to identify possible indicators to be used in a preliminary risk evaluation of buildings. The theme of the interviews are therefore limited to the following two statements.

- Identify possible indicators for fire risks of a building (FIs).
- Identify possible indicators for impacts a loss of a building would have on the business (BIIs).

Both of these above mentioned statements are concerned about exploration of knowledge of indicators, and the interviews phases should therefore also be carried out as such. This exploration is also one of the interviews pros because it allows the interviewer to follow paths in the interview that could lead to new discoveries [68]. This can be considered an alternative and creative way of indentifying indicators, because it depends on subjectivity, which then fits with the goal of the identification process stated in Chapter 3. The final theme of the interviews is therefore limited to.

- Interview theme: To conduct interviews as a exploration for identifying possible FIs and BIIs.

Interview design

The design phase of the interview process is where most of the planning for the interviews are carried out. It is therefore the purpose with this phases to create the foundation for how the interview are going to help achieving the goals set forth [68]. This phases therefore needs to specify the following two points.

- Who is going to be interviewed?
- What questions should be covered?

As it can be implicitly read from those two points is that they are the means to achieve the goal, because proper planning of them will get the knowledge that is needed. That is why this section is divided into two subsections where each of these two mentioned points are defined for this project.

Defining who the interviewees are

Defining the interviewees is important in order to ensure that the knowledge wanted came from the right persons. The choosing of interviewees is therefore not only important for obtain the knowledge but it also has to reflect that the knowledge is trustworthy. That is why the choosing of interviewees for these interviews had to be people that has experience with the two theme statements. Potential interviewees where found by brainstorming on which persons that could have knowledge about both statements, and therefore could see a relation in between them. The outcome of said brainstorm can be seen in Figure C.2.

From the figure can be seen that there has been defined five categories from there interviewees could be chosen from. These categories are defined because they are the ones that to some extent share an interest in fires for business's and therefore might have experience with both indicators for fire threat and business impact. However the categories scientific, legislation and specialist might not have substantial knowledge about BIIs and are therefore

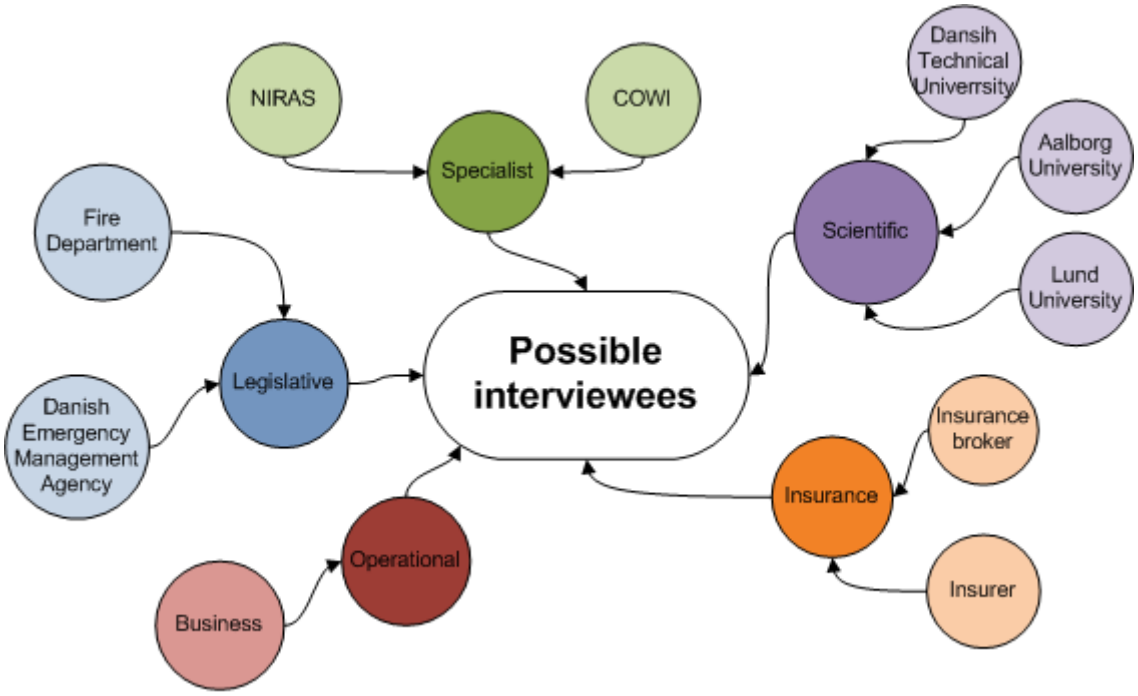

Figure C.2: A diagram of identified Interviewees that fits with the purpose of the interviews.

not encountered as primary interview subjects. This therefore limits the number from where interviewees can be chosen from to the following two categories.

- Operational

  Operational are referring to people that face the challenges a business has with fires and possible business impact, on a operational level. The right person from a business might have knowledge about what fire risks are faced in building and also have knowledge about how losing a building would impact the business.

- Insurance

  The insurances are chosen because they share the same risk as the business the cover by insurance. They are assumed to have an interest in reducing the damages from fires, by identifying the risk indications. But in the same time also posses knowhow of what the impact for different businesses would be.

From the two primary interviewee categories it was chosen to conduct interviews with four people. Where most focus was on the diversity of the businesses and therefore three interviewees came from the operational categories. Before moving on to the interview questions, a short presentation of the four interviewees is presented, to define who they are and what their strength is.

- Jesper Scott Johnsen (JSJ|Topdanmark)
  - **Background:** Jesper Johnsen is currently a Risk Engineer at the insurance company Topdanmark, as a educational background he poses a Civil engineering degree with a specialization within fire engineering. Jesper Scott Johnsen has furthermore, previously worked for COWI as a Fire Technical Consultant (JSJ|Topdanmark: 00:00-05:20).

  - **Relevance:** Jesper Scott Johnsen was chosen a relevant interviewee due to that he has experience fire risks in building within different businesses, as a result of his position in Topdanmark. it is assumed that the knowledge he could bring to the project is insight to how insurances identify fire risks in buildings. But also how they see a business being vulnerable to losing a given building.

- Flemming Damholt (FD|Danish Crown A/S)
  - **Background:** Flemming Damholt is a Fire Safety Officer at Danish Crown A/S and has previously worked as Fire Officer at Holstebro Fire Department, hes educational background is Building Construction Engineering.
  - **Relevance:** The relevance of using Flemming Damholt as an interviewee is besides from he's position and background, that he is working within a large business with responsibility for fire safety of a large building portfolio. Furthermore was Flemming Damholt after Danish Crown A/S had experienced a number of fires in their building, and it is therefore assumed that he has a really good knowledge of fire risks and impact of buildings.
- Ane Prehn Meyland (APM|Novo Nordisk A/S)
  - **Background:** Current position is Property Manager at Novo Nordisk A/S, previously also worked as Fire Safety Manager. furthermore has she worked for Gentofte Fire Department in position as Fire Chief Officer. In her educational background she holds an civil engineering degree with a specialization in fire engineering.
  - **Relevance:** The relevance of using Ane Prehn Meyland as an interviewee is that she posses practical experience of fire safety mitigation from both the Fire Department, insurance and the business side. Furthermore is it assumed that with a large amount buildings where in some chemical storage might take place, that she has knowledge about fire risks indicators for building and their impact.
- Lars Æbeløe-Knudsen (LÆK|Copenhagen University)
  - **Background:** Lars is a Administration Manager for all Copenhagen Universities buildings, He holds a Master degree in Public Governance. Is responsibility as Administration Manager is to handle the insurance, legal and economy issues that relates to Copenhagen universities buildings.
  - **Relevance:** Lars was chosen, because he is managing values of buildings, in a business that is financed by multiple investors. Furthermore it was interesting to look at how values of buildings are determined in a pace where the product is student and knowledge, and not a sold item on the market. The intention was to bring in another aspect of values into the project, and thereby see if there where any relation of values, for public owned buildings and private business.

Just to mentioned before moving on to the developing the questions, is that the Interviews were conducted in the same chronological order as they just were explained in.

Defining interview questions

The last part of the interview design phase is to develop the questions for the interviewees. This is a step not to be neglected because with proper questions planned it becomes easier

to obtain the needed knowledge from the interviews [68]. The questions are summed up in a interview guide, which is used to guide the interviewer to the needed knowledge that is wanted. The first step in this design guide was to develop questions that relates to the two theme statements, which means that the interviews are divided into two parts. The first part concerns the FIs where the questions are used to identifying possible fire indicators, and the second is related to the BIIs.

The structure of the interview guide is so that each parts start with broad questions to open as many doors in the beginning as possible. After that the questions becomes more specific to what knowledge is wanted. The interview guide are furthermore made up from a list of main question, again to open as many interview paths as possible. Then each of these main questions has a series of underlying questions that are used to supplement the main question with and specify it. Next is seen the Interview guide that was developed for this project.

1. Can you please introduce yourself?

   What is your name?

   What is your profession?

   What is your educational background?

2. What is an indication that a building is more susceptible to a fire?

   What is the fire risk?

   How does it state a building being more susceptible to fire?

3. What information would you use to evaluate the fire criticality of a building?

   Why would you use that?

   What does it state?

4. What general building information would state that a fire is more likely to occur?

   Could information from the BBR be used?

   What does the information indicate?

   How can the information be obtain?

5. How do you evaluate the most important building?

   What is the criteria?

   Why are those the ones that are used?

   Which of those criteria are most are weighted highest?

6. What are the most or least important building to the business?

   Why is that?

   What is it based on?

   how long can the business survive without it?

7. What are the short and long term losses for your buildings?

   What is the loss?

What is the affect?

8. What are the most important operations for the business?

   Can it be identified?

   How long would the business survive without it?

9. which building would have the biggest financial impact on the business?

   How is that defined or estimated?

As can be read from the Interview guide is that the first four main questions relates to discovery of FIs, where the last five relates to the BIIs. The focus when developing these questions was to ask general questions in order to identify as many indicators as possible, because for identification purposes it is not necessary that the indicators can be used as they are mentioned.

Conducting the interview

When it comes to conducting the interviews is was decided that the interviewees should not have direct knowledge of the exact questions that was going to be asked. The reason for this choice was to ensure that the interviewees did not take over the whole interview by answering the questions from the interview guide as they pleased. But by choosing to do so also means that the interviewees would not be well prepared for the questions, the quality of the answers would then therefore be optimal. To ensure that the interviewees therefore had the chance to prepare for the interviews without knowing the exact questions, then they were send a brief summary concerning the subject of the interview, which is seen next.

Summary In the interview we will be focusing on indications of fire related risks for buildings. The understanding of what makes a fire risk is based on two types of indicators.

1. Is an indication of what makes a building susceptible to a fire occurrence and is referred to as Fire Indicators.
2. Is an indication of business losses that could be experienced when losing an important building, which we refer to as a Business Impact indicator.

It is the purpose with these indicators to screen a buildings risk level, such that a preliminary detection of the most important and risky building in a building portfolio can be found to prioritize resources. An important criteria for this purpose is to be able to do it without having to physically inspect the buildings, using information that can be easily or quickly obtained. The interview will concern the following elements:

- What could be a Fire Indicator for buildings?
- What is an indication of a building with a higher risk for fires?
- What makes a building important to a business?
- What would be the related losses for businesses, when losing a building?

Transcription

The part of the interview process is where the interviews are transformed into written text. The traditional way of doing so is by writing down the interview word for word. It is a very time consuming process that may not be fully applicable in this situation. This is due to that the purpose is not the intention to use exact worded formulation from the interviewees to make a statement. For that reason it was chosen to make an interview overview that explains what information can be found in different time interval. This will be helpful to know what the interviews was concern about.

Interview 1 Jesper Scott Johnsen from Topdanmark

00:00-05:20 Introduction of Jesper Scott and he's profession.

05:20-06:50 What kind of information does he acquire before inspection of a building.

06:50–08:10 Explanation of how risk elements for buildings are created and measured.

08:10–09:13 What are the typical risk elements that are used.

09:13–11:46 What is the affect, for fire safety, that building materials has changed.

11:46–14:01 How does the risk picture looks like today with technical installations.

14:01–15:20 What kind of companies would more exposed to a fire risk than others.

15:20–18:09 The way the organization are med up affects the fire risks.

18:09–20:00 What information from the BBR can tell something about a building being more susceptible to a fire.

20:00–22:09 What is the indication of a buildings age, in regards to fire.

22:09–22:36 How Jesper creates a preliminary risk picture based on BBR information.

22:36–27:45 What kind of information can be obtained from the office to tell something about the fire risk of a building.

27:45–28:55 Has it occurred that the fire safety strategy is not up to date.

28:55–31:16 Which type of values does a building posses for a business.

31:16–33:38 Which values do Topdanmark look at when looking at a customers building.

33:38–38:34 What functional losses of a building could be important for the business.

38:34–39:43 What the strategic effect of losing a building are.

39:43–41:30 What the operational effect of losing a building are.

42:44–45:27 Does Topdanmark advise its customers on how they can ensure them self if a fire were to occur.

45:27–54:06 What would other risks for a business be, other than the Strategic, Operational and Financial risks.

54:05–56:51 Final comments on indicators for input.

Interview 2 Flemming Damholt Danish Crown A/S

01:52-04:20 Flemming introduces himself, what he does and what his experience is.

04:25-13:00 how he evaluates the importance of a building or what makes a building important to his business.

13:05-16:59 what is the most important building for his business

17:04-18:16 what is the disadvantage of having a smaller business or a small market share

18:20-25:30 how Danish Crown took back market share they had lost in the German Sausage market

25:34-27:53 what makes a building less important for the business, which buildings are less important and why are they less important than others

27:54-31:06 how Danish Crown has looked into keeping production going by looking at where and when they can stop production in the production line

31:08-32:54 which market is the most important to them and why they lost the Russian market share due to political reasons?

32:56-36:10 what would the long term business impact be if they lost their most important building?

36:15-38:10 what is the most important operation carried out and in which building is it?

38:20-39:50 how would a fire affect the employees that work in the building?

39:56-41:50 how the production in Horsens is carried out with regards to running time

41:55-45:09 what is the financial impact of losing a building and what it could impact?

45:16-50:25 how would you evaluate buildings with regards to which one has the highest fire risks and which would those be?

50:28-52:05 smoke is very risky for Danish Crown due the amount of stainless steel in the production and what smoke does to it

52:08-55:16 what general building information do you think could be used to say if a building is more likely to have fire?

55:19-56:15 Insurance premiums have been reduced significantly more than the amount that has been put into fire preventions

56:20-58:43 what made the fires in Danish Crown so big?

58:45-1:00:50 which of their building has the highest fire risk?

1:00:24-1:06:30 what general information would you like to have before going to inspect a building for likelihood of fires?

1:06:31-1:06:55 Finishing the interview

Interview 3 Ane Prehn Meyland from Novo Nordisk A/S

00:00-01:00 How to assess the most valuable building.

01:00-03:20 What is the value of production measured in.

03:20–04:30 How can the product value be measured for its competitiveness.

04:30–08:40 What else is important to the business beside from the production.

08:40–09:15 How does R&D affect the business, when the product is not developed.

09:15–10:10 How the reestablishment of R&D also affect the competitiveness.

10:10–15:55 What is the second most important buildings if production is the most.

15:55–17:10 Is there a differentiation in between what the product is used for.

17:10–21:15 How important is the building that carries out the logistics.

21:15–23:20 Can a supplier have a equally big effect on the business, as if it where the business own buildings.

23:20–24:20 What are the requirements for a business to survive without its building.

24:20–27:55 How important are the historical values.

27:55–32:25 How should offices be prioritized.

32:25–36:25 What are the effect of the buildings that delivers material to create the final product.

36:25–37:55 Does it matter to which country the product is created for.

37:55–40:10 How is quality prioritized.

40:10–43:40 How are values determined.

43:40–45:10 What are possible fire indicators of a building.

45:10–52:57 Is it possible to determine the fire risk by the age of a building without inspecting it.

Interview 4 Lars Æbeløe-Knudsen from Copenhagen University

00:00-01:18 Introduction of the project.

01:18-03:08 Presentation of Lars Æbeløe-Knudsen.

03:08–07:00 Which of Copenhagen University's buildings valued the most.

08:10–10:00 How is the value of a building determined.

10:00–15:30 What happen if a building is lost.

15:30–19:05 How to take into account the buildings materialized values.

19:05–22:15 How does the brand impairment affect the production.

22:15–27:26 What does loss of the building affect the business with.

27:26–28:26 What is the effect of losing interior of a building.

28:26–37:05 What new important values has emerged from past events.

37:05–39:20 What would the loss be, if it involves investors.

39:20–48:20 What is the effect from losing a protected building.

48:20–57:22 Final comments.

Analysis of interview

The analysis of interview is normally carried out in regards to the transcription of the worded formulation, in order to make statement. For the purpose of these interviews it is more necessary to identify possible indicators, and it is therefore not necessary to state if how the formulations could be understood. But in order to carry out somewhat of an analysis of what the finding in the interviews where, it was chosen to analyze what key finding in the different interview intervals where.

Interview 1 Jesper Scott Johnsen from Topdanmark

1. presentation
    - He is a civil Engineer with a specialization within fire safety.
    - has a Master in Fire Safety Engineering from DTU.
    - worked for COWI as a fire technical consultant for 5 years.
    - responsible for fire safety(1 year) for construction of a international airport in Uman (Ukraine).
    - Works for Topdanmark and has been there for 2.5 years, as a Risk Engineer.
2. What is the information he seek to obtain before a building inspection.
    - What is the activities that are carried out within the company, which is useful information before inspecting the building (5:53-6:07)
    - The place for where the building is located.
    - How does the building looks like.
    - Distance to neighbours.
3. Explanation of how risk elements for buildings are created and measured.
    - Elements for risk evaluations are based on statistical evidence of occurrence(7:25-7:30).
    - Use of information from previous events (Reports of huge events).
    - Information sharing from organisations.
4. What are the typical risk that drags attention.
    - It varies a lot on what risk element that drags attention, due to development.
    - back in old time it was more common to build buildings with brigs and today it is probably more sandwich elements.

- Pur (Polyurethan) Foam is not the best product to isolate with in regards to fire (8:40-8:48).

5. What is the affect, for fire safety, that building materials has changed.
   - There are pros and cons for the change to lighter materials that a building is build of, when it comes to fire safety.
   - There has been more strict requirement in building with PUR elements.
   - There are discussion about ease the rules for building with PUR elements, because of competition.
   - There is a higher chance that the building will burn to the ground if it is made with PUR(10:19-10:24)
   - Fires are something that always is present, but the causes changes and could be electrical installation(due to development from year to year), the risk picture changes with the development of technologies, (11:27-11:46).
6. How does the risk picture looks like today with technical installations.
   - If installations are made properly, then it should be reasonably safe (But that was also the picture for many years ago).
   - Installations has become more safe today.
   - But there has been a development that there are used much more electricity in buildings today, due to larger plants(Equipments/machines) that requires more.
   - More electricity that is a little more safe.
   - maintenance and operational use plays a role in how safe it is.
   - An company that produces a lot of dust creates a higher risk for fire start in technical equipment.
7. What kind of companies would more exposed to a fire risk than others.
   - Production companies are exposed to a higher fire risks than a office building.
   - carpentry business/auto paint company/auto mechanics are some of the kinds of companies that has a higher fires risk exposures.
   - The company's attitude towards the risks has an effect on the risks they are exposed to.
8. The way the organization are made up affects the fire risks.
   - you can best identify how the organization work by seeing it with your own eyes, through inspections.
   - Welding is a risk for fires, especially if it is close to fuel sources.
   - Control over the activities is one way of evaluating the company's organization.
   - auto mechanic shop has a statistical high risk for fires.
   - how you handle hot work determines the fire risk exposure.
   - how a building is divided into cells and sections is important to the fire safety.

- flammable liquids is an indicator for a fire risk, and how it is handled according to the regulations.

9. What information from the BBR can tell something about a building being more susceptible to a fire.
    - Information about what the building is made of(materials), which says something about what outer wall materials is used and the roofing material.
    - If a company splits is building into four buildings then it is deemed more safe.
    - Larger buildings creates a higher risk.
    - Distance between buildings also creates a higher safety. (can't be seen from the BBR)
10. What is the indication of a buildings age, in regards to fire.
    - Building age tells about how the building was made.
    - Electrical installation might be older, which makes them a higher risk for fires.
    - BBR might encounter flaws in its registry, because they are not updated.
    - Topdanmarks systems gets information from the BBR.
11. How Jesper creates a preliminary risk picture based on BBR information.
    - BBR does not necessarily always explain what the building is used for.
    - The usage of a buildings is information that is obtained through other means.
12. What kind of information can be obtained from the office to tell something about the fire risk of a building.
    - The usage is very important to get knowledge about.
    - The usage also indicates that there are other risk areas in a buildings, such as a kitchen.
    - It could be useful to know how the buildings is divided into fire sections and cells.
    - It could be useful to have a fire safety strategy report.
    - back in old times there was not a requirement for having a fire safety strategy report.
    - if there is made a reconstruction of a building then the owner has to apply for a new permission.
    - The rules for fire safety in buildings has changed, here materials that prove the safety of a buildings has changed according to what is needed to show.
    - back in the days the demands for fire safety was prescriptive rules, In 2004 came the regulations that changed this to a risk dimensioning approach, which gave more freedom for building a building.
    - the risk dimensioning approach made it easier to make larger rooms without fire sectioning it, which make the risk for insurance business larger.
13. Has it occurred that the fire safety strategy is not up to date.

- if changes in the building are made, then the strategy might not be realistic anymore.
- it is not seldom seen that the fire strategy is not correct, but it might not necessarily have to have an effect on the fire safety.

14. Which type of values does a building posses for a business.
    - Manufacturing companies are vulnerable in their production.
    - Manufacturing companies requires that their product is operational.
    - A machine value are best know by the company itself.
    - Loss of production is also best known by the company.
    - production loss has something to do with the company's sales and revenues.
    - Specialized machines can have a larger affect on the company and makes them more vulnerable.
    - The owner is the best informer for how much the building is worth monetarily.
15. Which values do Topdanmark look at when looking at a customer's building.
    - It is important to look at the cost of a building, as if it were to be rebuild.
    - the cost of a building depends on what it is made of.
    - It is also important to look at the equipments that is a part of the building.
    - they use the fordeling vejledning.
16. What functional losses of a building could be important for the business.
    - The functional losses depends on the business core services, product etc..
    - It also depends on how fast you can move/relocate the function to another place.
    - It also depends on how unique the equipment is, in terms of how long it takes to replace it.
    - It all depend on the type of company.
    - Supporting functions are less important.
    - It also depends on what can be facilitated to other suppliers.
    - The effect can also be based how long the product would be of the marked, and giving other competitors the opportunity to take over the customer's.
    - Competition is an important factor to take into account, when determining the potential effect.
17. What the strategic effect of losing a building are.
    - It can have an effect on the market shares.
    - If you are off the market for some time, will give competitors an opportunity to take over your market shares.
    - It can also have an effect on that the company would miss an opportunity to grow(develop).

- If you lose an opportunity to grow, then competitors might, grow from with better products.

18. What the operational effect of losing a building are.
    - Supporting functions can be important to a business, example if you cannot sell your product.
    - Office functions are often easier to replace or rebuild.
    - Office buildings are easier to replace than production.
    - The importance for office building is that they have ensured that the data they have is secured from a fire.
19. Does Topdanmark advise its customers on how they can ensure them self if a fire were to occur.
    - It is preferred to do pro-active measures.
    - They are more focused minimizing the risk for a fire to occur.
    - backup securing is important.
    - It can be a good idea to divide a buildings function into more than one building, to minimize the potential consequences.
    - Topdanmarks approach to risk reduction is to minimize the number of event occurring and the monetary values size.
20. What would other risks for a business be, other than the Strategic, Operational and Financial risks.
    - The three enterprise concepts are well covering for a business risks.
    - A business needs to think how it acts on the market, and how it is exposed to the surrounding.
    - The for food it can be important to think of if the food gets contaminated.
    - It is rarely that Topdanmark inspects office buildings and if, then it would be because it is really big.
    - it is rarely that fires occur in a office building.
    - The most interesting thing to be aware of in a big office building is the fire sectioning, if there is a kitchen function(a big one), Electrical installations, if there is larger areas that are under the regulations of "De driftsmæssige forskrifter".
    - You can minimize your risk a lot by splitting your company in to different buildings or sections.
21. Final comments on indicators for input.
    - How is the buildings production spread out on buildings/sections is important.
    - Does the activities involve fire risks.
    - What is the building made of.
    - How is the building divided into sections.

- What are the fire technical installations.
- Are there sprinklers that covers the whole building.
- Are there Automatic fire alarm system, and is it with a fast reaction.
- is it manned the 24-7.
- Are there production when people are not there.
- How is the organization does everyone know what to do in case of a fire.
- Are there active systems that prevents the reacts to the fire.
- Are there procedures for how reconstructions does now compromise the safety of the building.
- Are there develop control measures for when made a reconstruction.
- The position on their market is important.

Interview 2 Flemming Damholt Danish Crown A/S

1. Introduction of Flemming
   - He is the fire safety officer for Danish Crown group and has been there for 8 years
   - He is educated as a building constructer (bygningskonstruktur)
   - Has been a fire-fighter for many years
   - Has been involved with educating for fire-fighter on a national level in Denmark
   - Vice chief of a fire department in Denmark
   - Educated the people sitting at the local authorities in fire prevention
   - Was hired after 2 major fires in 2007
   - Has put in a program which started with investments in fire prevention, is in cooperation with the insurance companies was with AIG and is now in IF
2. How he would evaluate the importance of a building or what makes a building important for his business
   - A building is important based on what production is going on inside of it and how easy it is to replace.
   - In a big company like his there is normally spare capacity to put into production.
   - If the building like they have in Horsens is the building in question and he has to look at it if it possible to move the production to other places that is great, but if not then he has to make sure that nothing will happen to the building.
   - From an insurance point of view 25
   - Production and packaging are in different fire zones
   - Storage is not important unless it is finished goods, but they can build it up very quickly. Do not have a big storage because of the product they are producing.

- They do have storage of packing materials but it is low cost and they can replace it very easily within a few hours.
- Their main focus is always on having the production running
- Production is their most important criteria.
- The most important is what makes them the most money.
- They have a lot of very specialized equipment within the slaughtering of the pigs
- They have all critical spare parts in a centralized storage in Denmark

3. What is the most important building for his business?
    - The most important building is the building in Horsens because of the quantity of pigs they can slaughter. They can slaughter 120.000 pigs per weak where the next site can only do about 60.000 per week which is in Ringsted.
    - Having Horsens burn down and splitting the pigs on to the other sites is nearly impossible for them to do and that's why Horsens is so important.
    - They could kill them, half them and drive them to Germany to make the finished product
    - It is easy for them to manage their risk because they can spread their production over so many sites if anything happens to one of the sites
    - An example is that in May 2008 they had a fire on a Friday in Germany where they produce sausages. It was the ultimate high season for Barbequing and Olympics, tour de France and the European championship in football all taking place that summer. They had 75
    - Soup example (16:00-16:49)
4. What is the disadvantage of having a smaller business? (17:06-18:16)
    - If you have a fire and the production stops all the competition will go and steal your costumers
    - Customers might replace you because they find out there are other companies that can do exactly the same as you have been doing for them
    - So next time you have to negotiate with your costumer he might also want to have offers from others because he has seen that they can offer the same as you
    - Major part of small companies hit with a big fire will never go up again. (18:14-18:16)
5. How Danish Crown took back market share the had lost in the Sausage market
    - It takes a long time to take the market back and only happens because Danish crown wanted to
    - They could lower the prices to underbid the competition
    - It takes a lot of money to raise the brand up again
    - Competition is a very leading factor to what impact a fire can have to a business

- You can't be out of the market for too long or people will get used to buying the competitors product and it becomes a habit for them to buy that product instead of your product.
- There is no reserved money for taking back the market, it is just an investment the company has to take on
- Many factors dictate how long it will take to get back to the previous market share
- If you can distribute to other locations that is very good and also depends on the product that is being produced. If it is a product with a short expiry date then it is not so bad but if you have a product with a longer lifetime it might be a problem due to storage and such.
- They rely on storage for packaging materials and spare parts not their products
- Spare parts centre is in Esbjerg

6. What makes a building less important for the business, which buildings are less important and why are they less important than others?
   - Packing storage is less important because it is so easy to replace
   - Offices is not so hard to replace with some pavilion outside
   - The easiest to replace is the packing area because it is standardises equipment and it can be outsourced to another company or deal with in other facilities Danish crown has.
7. How Danish Crown has looked into keeping production going by looking at where and when they can stop production in the production line
   - He looks at what can stop the fire fighter for entering the building
   - People and animals have to be rescued before people so they are sectioned off(the pigs)
   - By using fire sections he can make the pigs safe and enable the fire fighters to not think of them and they can go and tackle the fire in the production because the pigs are in another fire zone
   - Minimize the spread of fire is very important
   - Production can be stopped when pigs are in the cooler and production can be stopped after that. So fire sectioning the right parts of the production line is very important to keep parts of the production going at the same location.
   - Cannot be split up to several building due to hygiene reason and they have to have the possibility to expand their facility
8. Which market is the most important to them and why they lost the Russian market share due to political reasons?
   - Chinese market is very important for them now because they don't have the Russian market anymore due to political reasons.
   - They are one of the only companies from Europe allowed to sell in china. It is a very important market for them.

- It is the most important market for them to protect so most money will go there

9. What would the long term business impact be if they lost their most important building?
    - The worst scenario will be to lose the Horsens site and the thinks it would take 5-8 years before Danish Crown would be up and running at the same capacity as they are today and perhaps more time
    - It will have a major influence on the company
    - Some workers would potentially be kept in Denmark but probably most of the work would be moved outside of Denmark
    - They would rebuild in the same location if it were the Horsens facility that burnt down because of the quality of pigs in Denmark and the quality meat
    - Possibly would be slaughtered in Denmark and then transported somewhere else to be fully processed, so they would possibly not build it up to the same level as it is now in Denmark
    - Some customers ask for Danish produced meat so some would be left in Denmark
    - Would affect the brand as well and cause some troubles with the insurance companies
10. What is the most important operation carried out and in which building is it?
    - Every operation is important as long as it is an part of the production
    - But the slaughtering of the pigs could be said to be the most important
    - If something is unique it is very important to a company
11. How would a fire affect the employees that work in the building?
    - They have 1800 employees in Horsens
    - When they had the fire in Blands they moved the employees to another location where they would slaughter in the weekends and they moved them around to finish their jobs
    - They are able to move them around for 1 to 1.5 years if needed
    - Big part of the employees are foreign, about 56-58 different nationalities in Horsens
12. How the production in Horsens is carried out with regards to running time.
    - They have two productions shifts and one cleaning shifts that work for five days out of the week
    - Weekends are used to run maintenance on equipment
    - It is possible to increase the production and move the maintenance back a little bit
    - Personnel are more or less at the site 24 hours of the day.
13. What is the financial impact of losing a building and what it could impact?
    - The most important is to get production up and running as soon as possible and they have a lot of room financial vice to get that done with in Danish crown

- One of the biggest problem for them would be to get re insured again
- An extra fire for Danish crown will make it very difficult for them to get insured again because they have had such big fires in the past
- Equipment would be a lot of a financial loss
- Business interruptions will be about 75

14. How would you evaluate buildings with regards to which one has the highest fire risks and which would those be?
    - Identify where a fire can start and where you have ignition sources
    - The second thing is to look at what can make a fire spread
    - And then keep these from the production
    - 80
    - So if you have electrical equipment it is important for them to isolate that from the production line and put it in some fire proof compartment that protects the product line and contains the fire from the electrical equipment
    - Keep ignition sources from combustible materials
    - Used a lot of money to take away ignition sources from the production line and to take the combustible material from the production materials and put into separate fire sections
    - Install smoke detectors
    - They placed hand extinguisher all over the production, the right ones.
    - They have very sensitive smoke detectors so people can react to warning very quickly
    - They have educated their employees with fire safety training and use of extinguishers
    - Sandwich panes with combustible materials inside
15. Smoke is very risky for Danish Crown due the amount of stainless steel in the production and what smoke does to it.
    - The smoke can react with the stainless steel and make it contaminated and thus food cannot be produced with that steel
    - Need to clean it up within 48 hours or production cannot take place and everything has to be changed.
    - They have very few sprinkler system because that pushes the smoke down to the level of the equipment
    - They would rather have the smoke up in the ceiling and vent it out than having it pushed into the stainless steel equipment
16. What general building information do you think could be used to say if a building is more likely to have fire?

- They have very old buildings that have been built on many times and no one has looked into fire protection
- Cables will be running through the additions without proper finishing
- Most old buildings made from bricks and from a fire perspective that is good
- Food production companies use a lot of sandwich panels
- Cheapest ones are eps, pir, polyurethane and if you have a fire in those they will burn down
- In their fires it was equipment, continuous additions to buildings
- Growth of the company had an effect on the fire safety

17. They have had a much higher reduction in premiums of insurance than they have spent on fire prevention
    - Fire prevention is a really good business and they have had a much higher reduction in their premiums than they have spent on fire prevention
    - They can go out to their customers and assure them that they can deliver because of their fire prevention
18. What made the fires in Danish Crown so big?
    - Combustible insolation was the biggest cause
    - Smoke damage
    - Polysterin will become a flammable liquid when on fire and spreads the fire very fast in the building
    - They only use the sandwich panels with the Rockwool insulation in now
    - Only use mineral panels
    - Only use flammable panels in the freezers now.
19. Which of their building has the highest fire risk?
    - That is the their USA sites because they treat safety in another way
    - Fire department do not extinguish fires in the same way, do it from the outside and don't go into the building
    - Electricity is treated very differently in the USA than in Europe
    - Buildings are built with a lot of combustible materials
20. What general information would you like to have before going to inspect a building for likelihood of fires?
    - He would ask himself three questions:
    - Which building material is used?
    - How old is the technical equipment?
    - Where is the plant rooms placed to the production?
    - Next things are:

- The usage of the building
- How the managers are looking at the risks inside the buildings
- Biggest risks for them are small electrical charging forklifts, which can be plugged in everywhere
- The fire in blands which is the biggest fire in Denmark was cause by a short circuit in a charging electric fork lift
- The way people think, how the management is handling things
- If the building looks clean on the outside the inside is probably clean as well
- And if the outside is a mess then it is most likely a mess on the inside
- How nice it is gives you an idea of how it is managed, best and first indicator you can look into
- Policies can be good but they have to be followed to work

Interview 3 Ane Prehn Meyland from Novo Nordisk A/S

1. How to assess the most valuable building.
   - Production buildings are the most important.
   - Especially the ones that cannot be backed up.
   - But it is also important to look at what kind of product the building produces.
2. What is the value of production measured in.
   - The product that leads to the largest loss in revenue is the one where most will be lost.
   - Business interruption is how you measure the biggest loss.
   - The longer time the product spend in the building the more vulnerable the building is.
   - one other parameters that plays a role in determining the importance of a building, is how important is the product for the end-user i.e. life threatening.
   - But it is also important how the competitiveness is on the market with the product made in the specific building.
   - For pharmaceutical business it is more important that it is the patient that is in focus.
3. How can the product value be measured for its competitiveness.
   - It is measured in would the end-user be able to get the product or similar elsewhere.
   - It does not matter how close the competition is.
   - It does not necessarily matter if the competitions product is of worse quality.
4. What else is important to the business beside from the production.

- R&D are also a critical place for the business to be interrupted.
- The R&D areas where the product is closer to be available on the market is much more important to the business, than other R&D.
- But what makes its impact less severe is that most of the R&D will be backed up and therefore easy to reestablish.
- Important parameters here are, where in the R&D phase are the product.
- What are the equipment requirements in for carrying out the R&D.
- Building where stages of the research are physically placed, can also be important because this could be lost research.
- Have to look at do you loss knowledge from losing the building's interior.

5. How does R&D affect the business, when the product is not developed.
    - The business will not have the newest product on the market.
    - The business might loss its patent, which results in competitors advantage of copying the same product.
    - Loss of patent will also result in lost investment in R&D.
    - Loss of patent results in loss of customers.
    - It is all about being competitive with new products.
6. How the reestablishment of R&D also affect the competitiveness.
    - There will be a larger loss in competitiveness if the R&D is more difficult to replace.
    - It is often more difficult to replace a R&D if it requires more specific equipment that is harder to come by.
7. What is the second most important buildings if production is the most.
    - The second most important are R&D or Pilot Plant.
    - Pilot plant are where the product is almost finished, and small amount of the new product is made, and is the step before the product is developed in a large scale.
    - Pilot Plant produces only products on trial basis.
    - Pilot Plants are important for the pipeline.
    - if there is only one large storage facility, then that would also be very important.
    - Storage is necessarily not that important, because the production can just be increased.
    - For pharmaceutical industries the documentation for the individual product, is also very important.
    - if documentation of a given product is lost then, the given product have to be pulled back from the market.
    - Loss of documentation of a product results in loss of sales and loss of reputation.
    - Bad reputation on one product might affect others made from the business as well.

- the business is very vulnerable if a product has to be pulled back from the market.

8. Is there a differentiation in between what the product is used for.
   - There is a difference in between what the products is used for.
   - There is a clear difference in what the product is used for.
9. How important is the building that carries out the logistics.
   - Logistic issues depends on how the business carries it out.
   - if a product stays a short time in one place, then that is not as important.
   - Suppliers that produces a product is also important for the business.
   - Supplier in this case is meant as the ones that produces the product for the business.
   - The business can be just as vulnerable on its suppliers as on its buildings.
10. Can a supplier have a equally big effect on the business, as if it where the business own buildings.
    - The supplier is equally important to the business as if it was its own production, but it depends on what the supplier delivers.
    - The impact will be determined the suppliers chance to deliver as well as their quality documentation.
    - It also depends on can the business survive without its suppliers.
11. What are the requirements for a business to survive without its building.
    - The most important part of the business is where the most yearly revenues are created.
    - It depends if the activities can be backed up.
12. How important are the historical values.
    - It affect the reputation.
    - it can have an effect on reputation so that products on the market will not be sold.
    - it could lead to that customers change their perception of the product, and then switch to another that seems more stabile.
13. How should offices be prioritized.
    - The office building that has a reputation, is more important.
    - It will affect the reputation if it is a building that people visits to see.
    - Reputational damage might depend on the size of the business.
    - An office building that does not necessarily expose a threat to the business reputation itself, but it can increase if the surrounding buildings are businesses that are vulnerable to the effect from the event.
    - one way to measure reputational risks, is by asking does the building have a reputation, does the business has a reputation and what are the surroundings.

- It is very difficult to measure reputation.
- Buildings reputational damage to the business might also change over time.

14. What are the effect of the buildings that delivers material to create the final product.
    - It depend on the importance of the end product.
    - The product of one product might be vulnerable in different stages of the production.
    - (Ane starts drawing different critical path in productions.)
15. Does it matter to which country the product is created for.
    - it depends on is the building is a part of the normal production flow.
    - It is important for the business to deliver the product to the respective market.
16. How is quality prioritized.
    - For pharmaceutical business quality is important, and are managed in small parts.
    - Pharmaceutical business should not compromise quality.
17. How are values determined.
    - The physical monetary loss of a building is not important, if the business interruption is a lot bigger.
    - It also depends on the capital the business has to building a new building again.
    - Physical values of building is only important if the business does not have the money to build a new.
    - Losing a building where there is no production, does not lead to any server business interruption.
    - Business interruption and quality documentation is the values of pharmaceutical business.
18. What are possible fire indicators of a building.
    - Fire risks of a building are the activities.
    - Other fire risks are the usage of chemicals.
    - The buildings condition also plays a role for how fire risky it is.
    - Age is an indicator for how it is constructed, installations age.
19. Is it possible to determine the fire risk by the age of a building without inspecting it.
    - it is possible if there is well documented internal information of building and the interiors age.
    - A building becomes fire critical after 15-20 years. which is mostly meant on the installation of the building, but also refers to the knowledge gained of the during that time.
    - The material and construction used from given years might today be considered a higher fire risks than when the building was made.

- But also today are used many plastic kind of materials that are more fire risk that other methods.
- There is still a lot of learning to gain from the way buildings where constructed previously.
- Building age as an indicator can be used to put building in a grey zone from where they would have to be checked if they are build the way that was the norm in that time.

Interview 4 Lars Æbeløe-Knudsen from Copenhagen University

1. Introduction of the project.
2. Presentation of Lars Æbeløe-Knudsen.
   - Administration chef .
   - master in public governance
   - Responsible for the economy of all Copenhagen University's buildings.
   - Responsible for the insurance and legal obligations of the buildings.
   - The University uses 400 million on its buildings.
   - The Building administration is divided into Maintenance, Construction, Planning.
3. Which of Copenhagen Univerity's buildings valued the most.
   - Copenhagen university has 923.000 square meters.
   - The total building value for all buildings is somewhere in between 10-12 billion kr..
   - Panum is currently the largest building with 140.000 square meters. with a monetary value of 2.2 billion kr.
   - 90-95% of all Copenhagen University's buildings are rented.
   - It is mostly the historical buildings of Copenhagen university that they own them self.
   - The original building value for the individual buildings, where made on the buildings functionality and the building's condition.
   - The most important buildings production-wise is Panum if asking the health science faculty.
   - The most important buildings in production is different from faculty to faculty.
4. How is the value of a building determined.
   - It is based on the property evaluation.
   - The buildings them self that are rented is not seen as a value to Copenhagen University.

- The production represented in a building has not been evaluated its worth because it is not owned.
- If looking at revenues then the Health science faculty represents approximatly 40% of it, but is only 20% of the total building square meters.
- The KUA 3 university building will be around 140.000 square meters, but will only represent 17-19% of the university's total revenue.

5. What happen if a building is lost.
    - if a building is lost, then the capacity of the building will be distributed elsewhere.
    - It is important to fire protect the object that has national interest and historical value.
    - There is no plans for business continuity.
    - It could be an option to distribute the capacity over other of Copenhagen University's buildings.
    - Renting of pavilions would also be an option to use for educational purposes.
    - It is important to know the landlord very well in such situations.
    - it is possible to rent space from other places as well, but with that follows a additional rental expense.
    - It might be more difficult to reestablish some functions like laboratories, because of need for equipment.
6. How to take into account the buildings immaterialized values.
    - There are values that has a historical value, which can be important.
    - The immaterialized values should be safely protected.
    - The image/identify of the business is an important factor to protect as well.
7. How does the brand impairment affect the production.
    - It is not likely that the university would get fewer students, if the brand is affected.
    - The revenue can determine which part of the business that is most important.
    - A large quantum of the revenue comes from research approximatly 70-80%.
8. What does loss of the building affect the business with.
    - It is possible that some of the object in a building cannot be remade, which is a eternal loss.
    - Research data might be lost if not backed-up.
    - It can be a challenge to secure some object from a fire, due to that they also have to be used.
    - Cloudburst safety has been a increasing focus.
9. What is the effect of losing interior of a building.

- To remake a stone collection with name tags, where worth 10-12 million kr. which went to employee salaries.

10. What new important values has emerged from past events.
    - The university experienced that there are some losses that might not even be replaceable, which posses a value that would for always be lost.
    - The non replaceable objects/values could only be valuable to a few people, for example scientists.
    - The non replaceable object/values, do not necessarily have a effect on daily activities.
    - The university have valuable object that has a great value for the nation, but little to the university.
    - A building can posses values that is of important to investors.
    - The university uses a lot of resources to mitigate on risky event such as fire, and are trying to incorporate more cross functional systems.
11. What would the loss be, if it involves investors.
    - If the safety of investors investment are deemed unsafely protected, then that could lead to the investors pulling back their investments.
    - The effect of a fire can damage the business brand in regards to its investors.
12. What is the effect from losing a protected building.
    - The image and brand would be effected if the building cannot be restored as it was.
    - There could be accessories to a building that might not be able to be restored, such as art.
    - Historical art on protected buildings at the university is not insured.
    - Some values of a building, is difficult to determine the impact of.
    - The materials used in a building plays an important role in the reconstruction of it.
    - The municipalities can have a saying on how a reconstruction of a building should be made.
    - Reconstruction of a building might not be restored as it was, it is likely that changes would be made, to make it more useful than before.
    - The way that the buildings are designed today can be different from when the building where build.
13. Final comments.
    - It is possible to drag parallels between how values of buildings are determined in private industries, and public buildings. This could be on areas such as Insurance, value determination, mitigation and research.
    - Art is difficult to replace.

- laboratories can have a high monetary cost.
- Any business is driven by a cash flow, where inputs are made to output.
- Operation that creates the output are relying on that the infrastructure of the business is doing well.
- Employees can have a very high value also in its reputation.

Validation

The validation phase is not of any sever importance for this interview process. This is because the validation carried out is to define if the findings even can be trusted and therefore used. Since the interviews are used to identify possible indicators, then the validation of said indicator would be carried out later on in the development of the indicator.

That being said it is of course important that the findings is somewhat reliable, so that the indicators pursued have a potential to become indictors. But this validation lies within the chosen of the interviews in the design phase of the interview, where only people that has experience with the two types of indicators are used. However there might be a possibility that the interviewees have mentioned indicators that may not be directly related, but that is a risk that is taken, in order to ensure a creative identification process.

The interview results

Presentation of interview results are shown in the identifications chapter 4.

Appendix D

BBR data parameters

This is the full list of categories and parameters that building and home owners are required to register in the BBR if they possess those parameters in their buildings or homes. This is a translation of the Danish law, for the original see "Bekendtgørelse om ajourføring af Bygnings- og Boligregistret (BBR) Bilag 1" which can be found at the following website `https://www.retsinformation.dk/pdfPrint.aspx?id=143662`.

For the individual ground

- Drainage
- Water supply

For the individual building

- Building usage (Which has six main usage types)
- Year of construction
- Rebuilding of and additions age
- Outer wall material
- Supplemented outer wall material
- Roof material
- Supplemented roof material
- Area
- Building area
- Number of floors in the building
- Total building area
- Area of built-in garage
- Area of built-in outbuilding
- Area of built-in sun lounge or the like
- Covered area
- Area of garbage room at ground level
- Amount of exterior area that has been additionally or after isolated
- Other area
- Deviating floors
- Heating installation in use
- Heating medium in use
- Additional heating installations used
- Drainage and water supply
- Number of apartments with kitchens
- Number of apartments without kitchens
- Sikringsrumspladser
- Building insurance

For the individual staircase

- Number of person or service elevators

For the individual floor

- Total area of the floor
- Area of the utilized portion of the top floor
- Basement area with a ceiling less than 1.25 m above ground
- Area of legal settlement in partially exposed basement
- Floor type

For the individual residential or business unit

- Residential and commercial unit's usage
- Apartment type
- Areas
- Total unit area
- Unit area for residential purpose
- Unit area for business purpose
- Number of rooms in residential or commercial unit
- Number of rooms for a business in the unit
- Toilet facilities
- Bathing facilities
- Kitchen facilities
- Heating installation
- Heating medium
- Additional heating installation

For the individual technical installations

- Oil tanks
- Wind turbines

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