LLOYD'S

360

DRIVING THE DEBATE ON EMERGING RISK

COASTAL COMMUNITIES AND CLIMATE CHANGE

MAINTAINING FUTURE INSURABILITY

RMS®

ClimateWise
REDUCING THE RISK FOR TOMORROW

Lloyd's is one of the founder signatories of the ClimateWise principles. ClimateWise is a group of leading companies and organisations in the insurance industry committed to taking action on climate change. The ClimateWise signatories will raise climate awareness, carry out research and analysis, and inform and engage in public policy debate. We hope that this report helps to encourages the public, businesses and other stakeholders to consider adaptation against the coming change.

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COASTAL COMMUNITIES AND CLIMATE CHANGE

MAINTAINING FUTURE INSURABILITY

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FOREWORD
FROM LLOYD'S CEO

In this, our fourth, 360 risk project report on climate change, we have teamed up with Risk Management Solutions (RMS), the world's leading catastrophe risk management company, to look at how measures of defence against flooding could help to maintain the affordability and availability of insurance in the future. It forms part of our ongoing commitment to the ClimateWise principles to carry out and share research into climate change.

Climate models clearly show that our weather patterns are changing and that as a result sea levels will rise. The consequences of this for many coastal communities will be devastating. Even a 30cm rise in sea level by the 2030s could double the losses from damage to a high-risk property located on the coast.

Mitigation through reductions in greenhouse gases is the only way to solve the global problem of climate change in the long term. But, with more than half of the world's population expected to live within 100km of the coast in 25 years' time, it is imperative that we also address this risk now by starting to adapt.

Using a series of examples, this report demonstrates the benefits of a variety of adaptation measures. In addition to reducing the levels of damage suffered by owners of businesses and homes, these measures will also maintain insurability in the longer term.

Insurance will continue to play a key role in helping coastal communities to prepare for and recover from storms and flooding associated with climate change. However, without the kinds of adaptation strategies discussed here, the overall affordability and availability of property insurance will be affected.

The global insurance and reinsurance industry has a vital role to play in promoting the benefits of adaptation to policyholders.

Richard Ward
Lloyd's CEO
September 2008

EXECUTIVE SUMMARY

Many coastal property owners rely on insurance to help manage the risk of flooding. However, despite widespread concerns about the affordability and availability of property insurance in coastal areas, few people are currently considering how the insurability of their homes and businesses might be affected by increases in risk due to climate change.

1 IF NO ACTION IS TAKEN, LOSSES FROM COASTAL FLOODING FOR HIGH RISK PROPERTIES COULD DOUBLE BY 2030. THEREFORE, ADAPTATION IS VITAL

While mitigation through reducing greenhouse gas emissions is the only effective way to turn the tide of climate change, adaptation is vital given the potential future rate of climate change.

2 WITH AN EFFECTIVE ADAPTATION STRATEGY, FUTURE LOSSES CAN BE REDUCED TO BELOW PRESENT DAY LEVELS

In almost every case study in our report, adaptation would reduce losses resulting from climate change in the 2030s to less than the present day. The losses for high-risk properties could be reduced by 70% through using flood defences together with flood resilient and flood resistant measures.

3 THE INSURANCE INDUSTRY CAN ENCOURAGE ADAPTATION BY POLICYHOLDERS THROUGH INCENTIVISATION

Governments and insurers can play a key role by providing further financial incentives for adaptation; for instance, they can set policy premiums at a level that more closely reflects the risk to which individual properties are exposed. If adaptation measures are not implemented, insurance will become more expensive and less available.

4 ADAPTATION STRATEGIES MUST BE TAILORED TO INDIVIDUAL LOCATIONS AND CIRCUMSTANCES

There is no single solution for managing coastal flood risk for all future situations or eventualities. Society will need to be flexible enough to take account of the uncertainties surrounding the consequences of climate change.

5 CURRENTLY, POOR LAND USE POLICY AND INCREASING URBANISATION ARE KEY DRIVERS OF RISING FLOOD RISK

Climate change adaptation measures must therefore take account of other factors that affect flood risk in coastal areas, such as planning policies.

6 THE WORLD CANNOT INSURE ITS WAY OUT OF CLIMATE CHANGE

Insurance is an effective way of managing individual risk that cannot be dealt with by adaptation. Adaptation and effective risk-informed development planning are the only means of reducing total risk.

METHODOLOGY

This report looks at the impact of climate change on flood risk at a number of coastal locations around the world, considering sea-level rise, the effect of wind speed on storm surges and, at one location, changes in land use. It investigates the impact on:

- **An unprotected property with no flood defences on a Caribbean island, the coasts of which are exposed to hurricanes and their associated storm surges.**
- **A building on the coast of a northern European country protected by flood defences against up to a 1-in-100 year storm surge event.**
- **A property on the coast of a northern European country, not protected by flood defences.**
- **A coastal city in Southeast Asia, with no flood defences, in terms of the risks from river flooding.**

While the analysis uses case studies of individual properties, the broad conclusions remain valid for businesses and other buildings in similar locations.

Losses have been estimated for three broad scenarios:

- Present-day risk.
- Future risk in the 2030s under climate change, without adaptation.
- Future risk in the 2030s under climate change, with adaptation.

The key metrics used in this report are the average annual loss and the 1-in-200 year return period loss. The 1-in-200 year return period is used for illustration purposes, as it is the level of risk required by the UK regulator to calculate the amount of capital that insurers are required to hold to cover risks. The average annual loss is a useful metric because it relates to the 'technical price of risk' and is, therefore, relevant to insurers in setting insurance premiums.

For these case studies, the data has been drawn from real-life examples in different locations. This means that the results should be treated as illustrative rather than definitive – they highlight the potential scale of changes in loss in representative circumstances. This study also does not provide a cost-benefit analysis of adaptation; it focuses on the benefits of adaptation in terms of the reduction in loss.

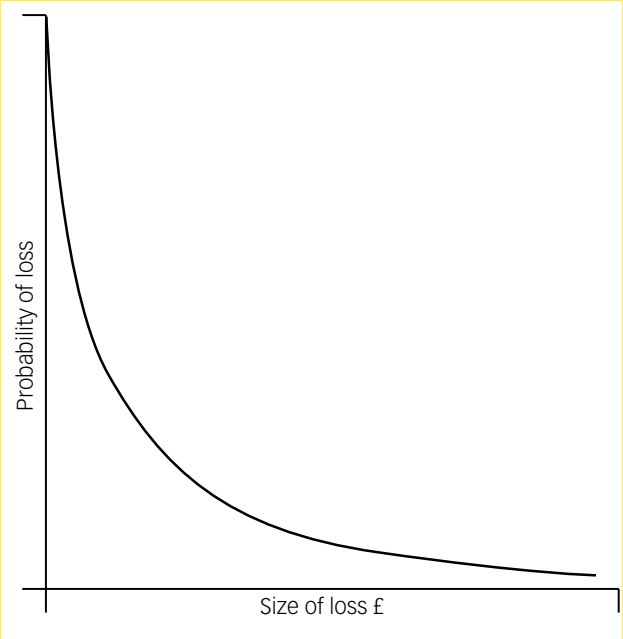
The scenarios have been investigated using climate change and/or land-use change projections from scientific literature. The properties considered are all close to the coast and are at high risk from sea-level rise, and consequent increases in storm-surge.

TERMINOLOGY

This section gives a brief explanation of some key terms used in the report that may not be familiar to those outside the insurance industry.

EXCEEDANCE PROBABILITY (EP) CURVE

The main output from catastrophe modelling is the EP curve – see the simplified picture below. This gives an estimate of the probability of total claims (the 'loss') being larger than ('exceeding') a certain size over a specific period eg a year.



The higher the loss (ie the more damaging a catastrophic event is, or the more policyholders that are affected), the lower the probability of that loss being exceeded. Typically, the larger the event, the less likely it is.

Using the EP curve we can derive average losses over a year. In most years we do not expect any loss from catastrophic flooding (ie the most likely outcome is that there will not be a major flood). But if there is a flood, losses can be considerable. When we average these losses over time we can arrive at an average loss per year, which is a key factor in determining the premium charged for policies. In this report, when we make reference to 'average losses', we always mean per year.

RETURN PERIOD

If the EP for a given size of loss is 5%, then we might also say it has a 1-in-20 chance of occurring in any given year or has a return period of 20 years. Put another way, during a 20-year period we would, on average, expect to see the given loss in only one year. The 'return period' in this example is 20 years. But this does not mean that losses of this size will be spaced exactly 20 years apart. It is an average, and it is, therefore, possible to have that level of loss more than once in a 20-year period, and even in subsequent years, or not at all.

Return period can also be used to describe individual events that cause a loss. For example, flood walls might be built to a height designed to withstand a 1-in-100 year event. We have used both meanings in this report. Return periods are not static, however. Changes in the frequency, average severity of events and our evolving understanding of the risk influence the calculation of return periods. This is a crucial point because climate change means that return periods could change quite significantly. Therefore, the safest interpretation is to consider a return period as describing the probability over the next year, rather than any longer period.

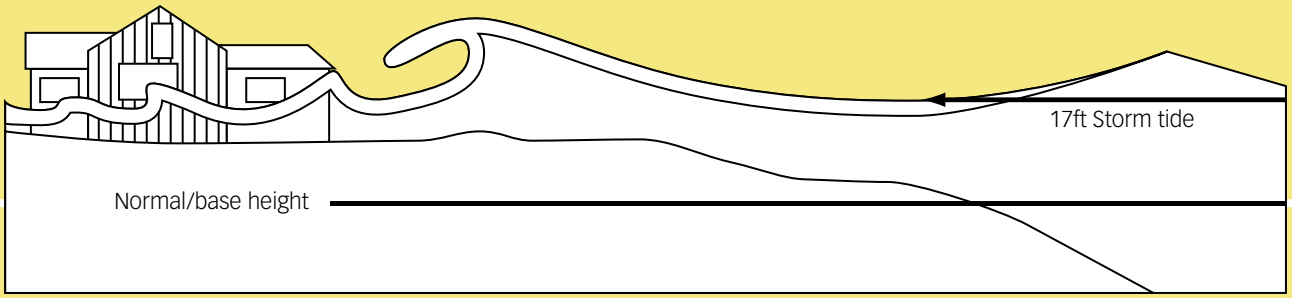


Figure 1

STORM SURGE

Flood damage can arise from several sources:

- Rivers overflowing, typically caused by either very intense rainfall over a large area, long-duration rainfall events or rapid snow melt (commonly referred to as 'fluvial' flooding).
- Flash-flooding arising from heavy downpours in small river channels or drainage pathways; and overwhelming drainage systems causing surface water flooding (commonly termed 'pluvial').
- Coastal flooding from storm surges.

Storm surges are the result of high winds on the surface of large bodies of water, such as seas and very large lakes, increasing the level of the water above the normal (or 'base') height. They are caused by a combination of two main factors. First, as a storm is an area of low pressure, the surface of a body of water below it tends to be sucked up to a higher level than under normal atmospheric conditions. Second, and more importantly, strong winds push the water ahead of the storm, building up a wall of water that can be several metres high. The combined result is an increase in the level of water, which when it hits a coastline, will flood the area inland if it is not sufficiently protected. The most dangerous conditions are often created when a strong storm is combined with high tides and low-lying coastlines.

Storm surges can have devastating effects. The widespread flooding along the east coast of Britain in 1953, which resulted in more than 300 deaths, was caused by a storm surge. Recent research by RMS for the Association of British Insurers (ABI) suggests that a repeat of a similar storm surge today could lead to financial losses of around £2.5bn. The catastrophic flooding of New Orleans in 2005 was also triggered by a storm surge ahead of Hurricane Katrina, which overwhelmed the city's flood defences.

The magnitude of storm surge risk in the future could potentially be affected by two climate change factors:

- The heating and expansion of the Earth's oceans, coupled with the melting of land-based glaciers and ice sheets, is causing global sea levels to rise, elevating the base height of storm surges.
- The characteristics of storms could change, for example, driving more intense and/or frequent surges.

Sea-level rise in general can threaten regions without a storm surge, and can also lead to sudden landslips. These are important issues that should be considered, but they fall outside the scope of this report. This report mainly considers flood risk caused by storm surge in coastal regions. However, our example in Southeast Asia also looks at river flooding in a coastal city.

PHYSICAL ADAPTATION OPTIONS

A range of physical adaptation options against storm-surge flooding have been considered. These fall into three main types:

- **Hard engineering, such as flood defences (eg sea walls).**
- **Elevating a property, for example, on stilts or by raising the floor.**
- **Changes to the characteristics of a property to make it more resilient and resistant to flooding.**

Some of the suggestions explored here require only limited advance planning (eg moving valuables upstairs or having sandbags and temporary flood walls), while others are more extensive, and require professional design and installation.

This is not an exhaustive list, and our case studies aim to simply illustrate the impact that adaptation can have on reducing risk. When thinking about adaptation, all options should be considered, including those which speed up the recovery process, such as flood proof flooring and wall finishes.

The adaptation options considered below will reduce the risks faced by the property owner. A property that has not been adapted is not as valuable as one that has. Therefore, household and business property valuations should take account of levels of future risk and the availability and future cost of insurance.

FLOOD DEFENCES

Flood defences (including dykes and levees) are a common form of defence against storm surge flooding in the UK and many other countries, usually protecting concentrations of coastal properties. Not only must they withstand the mass of water associated with a storm surge, but they need to resist erosion by crashing waves.

Flood defences are generally built to provide protection against storm surges of a certain severity. In the UK, many coastal towns are defended against at least a 1-in-100 year risk of flooding. The Thames Barrier was designed to protect more than one million people in London against at least a 1-in-1000 year risk of flooding until 2030. Flood defences cannot provide protection against all storm surge events. A surge of a higher level than that which the defence is designed to withstand would overtop it. In addition, flood walls cannot always offer 100% reliability, and can fail even when subjected to a flood event below the designed level of protection (as was seen during the flooding of New Orleans in 2005).

Construction and maintenance of flood defences is often undertaken by national or local governments to protect whole communities. While expensive, such defences can be highly effective. In the UK, the Department for Environment, Food and Rural Affairs (Defra) estimates that a coastal flood defence costs an average £1,600 per metre to build, with additional maintenance costs.

ELEVATING EXPOSED PROPERTIES

One obvious way to protect properties from flood damage is to elevate them above the height of possible flood waters. Buildings in many locations that are prone to storm surges are already built on stilts, for example, in the Florida Keys.

Elevation of an entire building is usually only undertaken if it has a high chance of severe flooding, and is most cost-effective when carried out during construction, or re-construction after being flooded. Depending on the design, it could also be possible to elevate an existing property, but costs may be prohibitive.

The ground floor of an existing building could be raised above the flood depth, provided the ceiling is high enough. For existing buildings this is not a trivial option; if all doors and windows also needed to be raised, the Association of British Insurers (ABI) estimates that this could cost more than £30,000 compared to a typical rebuild cost of £60,000 to £100,000 for a typical domestic property.

FLOOD RESILIENT AND FLOOD RESISTANT MEASURES

There are a number of other ways in which an individual property can be adapted to make it less susceptible to flooding:

- Flood resilient measures, which aim to limit damage when flooding occurs, and speed up recovery (see Figure 2).
- Flood resistant measures, which aim to prevent water from entering the property (see Figure 3).

We have explored six types of building alterations to increase resilience and resistance against flood damage, some of which are more applicable to new builds, while others are suitable for retrofitting an existing property. The cost and effectiveness of each of these measures will depend on the physical properties of the building and its location.

Engineered foundations
Foundation systems anchor a property to the ground, so poor foundations can lead to structural damage and instability if the building is flooded. An engineered foundation system is one that has been specifically designed to be resilient and resistant to flooding. This can help maintain stability and limit structural damage if the building is exposed to severe flooding (ie deep water), rapidly flowing water or waves (ie affecting properties on the seafront). The system might include strengthened anchorage, improving resistance to erosion caused by flooding and construction with impermeable materials. Engineered foundations are generally applied to new buildings, but may be added to existing structures that are at high risk of severe flooding.

Reinforced cladding
Cladding is the protective layer covering the exterior structure of a building. For a home, it might be brick, stone or wood, and for an industrial or commercial building it might also be corrugated metal or glass. Reinforced cladding can limit structural damage in the event of flooding by resisting the pressure of water on the building and reducing damage from any flood-borne debris. As with engineered foundations, this measure provides most benefit for buildings exposed to fast-flowing water or severe flooding.

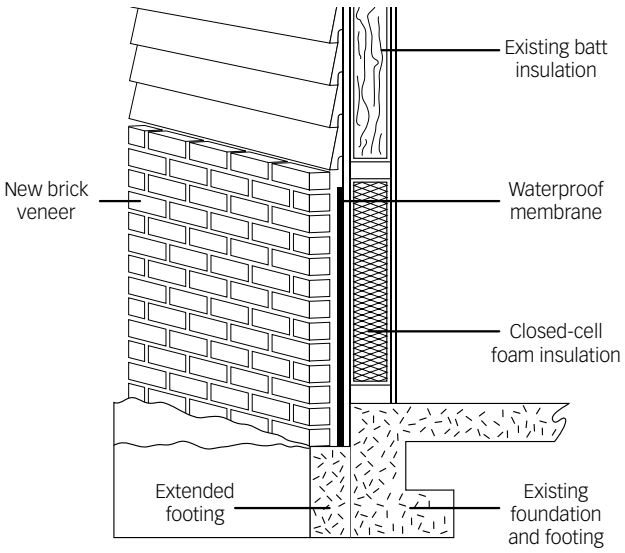


Figure 2

This means that it is one of the most cost-effective measures for protecting buildings at high risk. Reinforced cladding is more easily applied to new properties, but depending on circumstances, may also be used on existing homes, particularly if under repair from flood damage.

Cladding can be waterproofed as a form of flood resistance. However, this measure is not always suitable. For example, if a building is exposed to deep flooding, it can actually lead to more damage from the additional water pressure on the walls.

Protection of external electrical and mechanical equipment
Electrical and mechanical equipment outside a building (eg lighting, garden equipment, security systems and gas meter) can be easily damaged by flood waters. Raising equipment above potential water levels, or protecting them from water, can reduce or eliminate damage.

Adapting a property in this way can be particularly cost-effective if carried out during the course of repair or renovation.

Moving building contents out of the reach of flood waters
In case of flooding, high-value items, such as furnishings and electrical devices within the property, should be moved out of the path of flood waters to limit damage. In areas at risk of severe flooding, it can be appropriate to move high-value items permanently out of danger, for example, by storing computers and media equipment on the upper floors, mounting white goods on plinths and moving the kitchen and heating system upstairs. Moving a kitchen and heating system is a costly option, but can be achieved more easily and cheaply if done in the course of repairs, as evidenced in the English city York and parts of Germany following heavy flooding over the last decade. Tiling ground floors and using removable rugs, rather than carpets, will also limit damage.

Flood wall around an individual property
A flood wall is a free-standing barrier used to prevent water from entering a property. It can, for example, be permanent or temporary and made up of sand bags, a demountable steel barrier or a free-standing concrete barrier.

The advantage of a flood wall is that it can be easily applied to an existing property, and has benefits for both shallow and deeper floods. A disadvantage is that some water can seep

under the barrier, particularly into low-lying areas such as basements, so measures may need to be taken to waterproof the building as well. There is a risk that temporary barriers may not be erected in time to be effective.

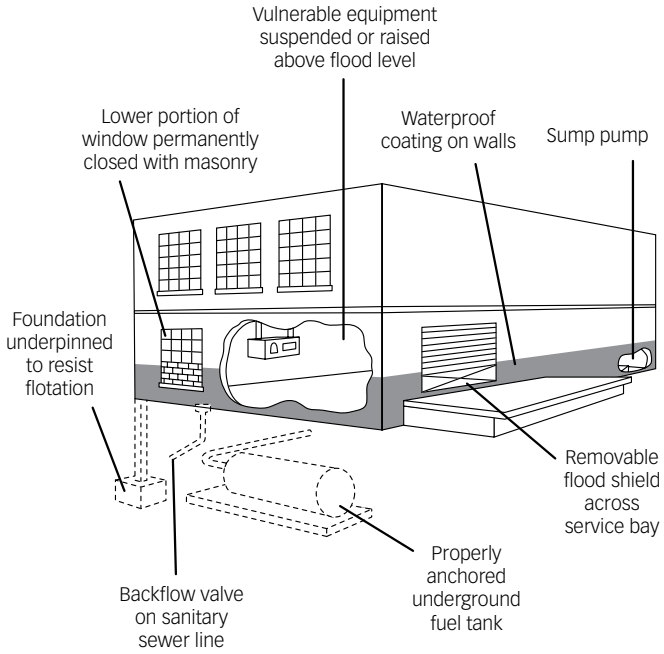


Figure 3

Dry flood proofing

The aim of dry flood proofing is to stop water entering a property. To achieve this, all areas below the flood protection height must be made watertight. This involves a range of measures, such as adding waterproof membranes to the exterior walls, placing temporary watertight shields over doors and windows, installing backflow valves in pipes and applying plastic covers to air bricks.

Dry flood proofing can be effective in reducing damage from less severe flooding, but it is not suitable for properties at risk of very severe flooding (ie flood water levels of greater than 90cm) as the pressure of water on the structure can lead to collapse. Reinforced cladding and engineered foundations help to resist this pressure and maintain stability. This measure also requires the homeowner to have adequate warning time to put in place the temporary measures. For these reasons, dry flood proofing is generally less effective than a permanent flood wall.

POLICY AND FINANCIAL ADAPTATION OPTIONS

While we have focused in the report on three main ways of managing the risk of storm surge flooding, there are other methods of adaptation that may also help to manage the threat. A key policy point is that consideration should be given as to whether to continue development on some flood-prone areas, and whether this continued development creates a threat to insurability.

Informed spatial planning

Even without climate change, the number of properties exposed to storm surge flooding will increase due to the growth of coastal developments around the world. In many areas, coastal properties are highly desirable and highly valued. For example, in Florida the population in coastal counties grew from 5.5 million in 1980 to 9.7 million in 2003. In this state, 80% of insured assets are near the coast.

In the UK, pressure for more housing has led to plans for extensive development in the floodplain areas. Research by the ABI has found that one third of the area of the government's designated four main growth sites (with up to 108,000 homes) are located on coastal and river floodplains. This includes the Thames Gateway region, where more than 10,000 properties may be at significant risk from flooding if defences are not improved.

The ABI has called for tougher planning controls, suggesting that of three million new properties planned to be built by 2020, around a third will be on coastal and river floodplains, despite Environment Agency advice to the contrary. The ABI has warned that poor planning decisions may lead to buildings being uninsurable in the future. ABI's recently revised Statement of Principles commits to providing flood coverage until 2013 to existing houses that lie within 1-in-75 year risk zones; but they have not extended this to newly built properties.

Informed spatial planning policies that discourage property construction in the areas most exposed to storm surges could significantly limit and reduce risk. Planners should also consider approaches to limit the risk of flooding in developed areas, such as making space for water and sustainable urban drainage systems, like permeable pavements or 'soak aways', and build properties to be resilient.

Risk assessments for planning and development must be based on up-to-date risk models, and also take into account the likely evolution of risk over the lifetime of the development,

including factors such as climate change. This is not the case currently. For example, in the US developers are required to plan for a 1-in-100 year flood based on Federal Emergency Movement Agency (FEMA) flood maps. However, these give no information about future flood risk. Similarly, in the UK, flood maps published by the Environment Agency only provide information about the current risk of storm surges. The latest guidance, Planning Policy Statement 25, suggests that 'new developments should be planned to minimise future vulnerability in a changing climate'. There must be clear guidance on planning restrictions, and these must be enforced.

Property insurance

Insurance is a key tool for risk managers, whether company directors or Homeowners, to reduce their individual financial exposure to extreme events. It helps to speed the recovery of those affected by catastrophic events, maintain business continuity and reduce individual suffering. However, insurance does not provide the whole solution.

The world cannot insure its way out of climate change. Insurance is an effective method to manage the individual residual risk that can not be eliminated cost-effectively by adaptation. In order to slow down or reverse sea-level rise, we must first reduce the emission of greenhouse gases in the atmosphere. However, adaptation and effective risk-informed development planning are the only effective means of reducing total risk.

Insurers can play a positive role in adaptation by enabling individuals to understand the risks they face and promoting adaptation investments. Property insurance can encourage adaptation only if premium prices first reflect the risk to which properties are actually exposed, ie risk-based pricing. Then an insurer can incentivise measures taken to reduce risk by correspondingly lowering insurance premiums. For an insurer this could have the direct advantage of lowering the volatility (frequency and severity) of claims.

CASE STUDIES
UNDEFENDED ATLANTIC TROPICAL COASTLINES

In this example, we consider a two-storey residential property on a small island state of the Caribbean. Such islands, and low-lying coastal areas along the Gulf of Mexico, are likely to be highly exposed to climate change, in terms of sea-level rise and changes in the frequency and/or intensity of tropical storms.

In this case study, the impact of climate change on storm surge risk is investigated by considering a sea-level rise of 30cm accompanied by three potential scenarios for tropical cyclone activity in the 2030s:

- 30cm sea-level rise and no change in tropical cyclone activity from present-day levels.
- 30cm sea-level rise accompanied by a 5% **increase** in the number of category 3–5 tropical cyclones compared with present-day levels.
- 30cm sea-level rise accompanied by a 5% **decrease** in the number of category 3–5 tropical cyclones compared with present-day levels.

Science does not yet allow us to say with certainty which of these scenarios will occur. While the proportion of stronger hurricanes in the North Atlantic has increased since the 1970s, there is no consensus among researchers about whether this is the result of climate change. Computer models of tropical cyclone activity currently suggests that climate change will result in a global increase in intensity and a decrease in frequency.

A small tropical island is an interesting case study as it is less likely to have coastal flood defences so adaptation may be at the household level. For example, in Grand Cayman, property owners have already begun to invest in measures, such as elevating residential buildings on stilts to protect them from smaller storm surges, following the 2004 Atlantic hurricane season. This study explores the effect of elevating the property on stilts by 50, 100 and 150cm, as well as specific flood resilient and flood resistant measures.

For illustration purposes, we have chosen a site with a high present-day risk from coastal flooding. However, the proportional increases in risk can be considered representative of changes at lower risk locations.

RESULTS

Present-day risk

The site used in this case study, with a total insured value of $300,000, would experience an average annual loss of slightly over $5,000 from storm surge damage alone.

If no action is taken

By the 2030s, sea-level rise of 30cm alone could increase future average losses by more than 80% from present levels, meaning that more extensive damage will be experienced more often. An increase of 5% in the number of more powerful hurricanes would raise future average flood damage losses to more than 90% above present levels. Even with a decrease in the number of storms, future average losses would be around 70% above present levels.

ELEVATING THE PROPERTY

This significantly reduces future average losses. Raising the property by 50cm on stilts lessens future average losses by more than 60%. Future losses associated with an extreme 1-in-200 years event are reduced by about a quarter, to lower than present levels. Elevating the property on 150cm stilts reduces future average losses by more than 95%, and 1-in-200 year losses by more than three quarters.

ADAPTING THE PROPERTY WITH FLOOD RESILIENT AND FLOOD RESISTANT CHARACTERISTICS

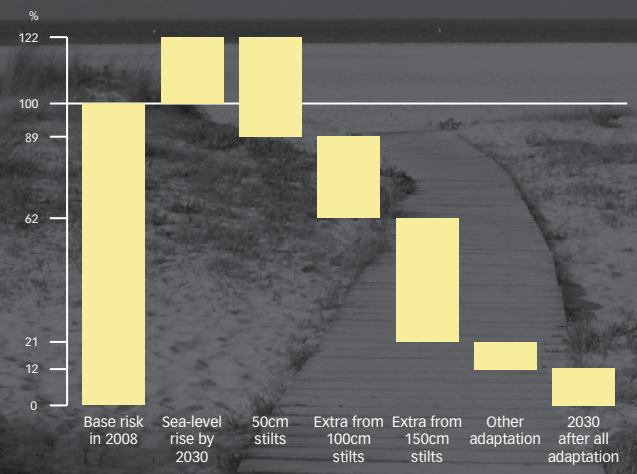
Employing flood resilient and flood resistant characteristics alone reduces future average losses by 10% and extreme 1-in-200 year losses by 35% of present-day levels. However, the impact is not as significant as the use of stilts.

Combining resilient characteristics with 150cm stilts reduces future losses to 3% of present-day levels and 1-in-200 year losses to just over 10% of present-day levels.

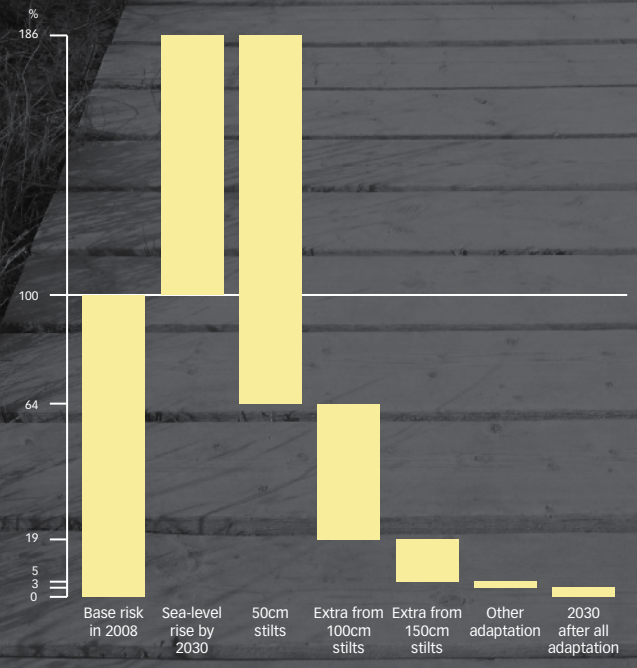
CONCLUSIONS FROM THIS CASE STUDY

- Properties along the coast of Caribbean islands and along the Gulf of Mexico face future increases in potential average losses from flooding due to the combined effects of sea-level rise and changes in hurricane activity.
- The risk of losses can be substantially reduced by elevating exposed properties, for instance on stilts, or by making buildings more resilient and resistant to flood-water damage. In some cases, losses can be reduced to below current levels.
- New building in highly exposed coastal areas should be considered carefully, particularly in light of possible extreme sea-level rise later in the century.

Effect on 1-in-200 loss



Effect on average loss



CASE STUDIES
DEFENDED NORTH EUROPEAN COAST

In this example, a standard two-storey residential property, used as a single family home, was considered in the light of present-day data for the UK. This property is in a relatively high-risk coastal location, but is assumed to benefit from well-maintained flood defences designed to provide protection against flooding from extreme events that would occur every 100 years on average. This means that the sea defence walls would need to be about six metres high.

The future climate change scenario assumes a sea-level rise of 30cm by the 2030s, but no increase in the frequency or intensity of windstorms.

Two adaptation approaches are explored:
- The raising and enhancement of flood defences.
- The installation of a suite of property-level flood resilient and flood resistant measures.

RESULTS

Present-day risk
At present, if the property has a total insured value of £180,000 it would experience an annual average loss from extreme flood damage alone of just over £2,000. This loss is driven entirely by the small (less than 1%) probability of a high-impact extreme storm surge overtopping the defences.

Ignoring any change in windstorm activity, if the same property were located around one metre higher, the average loss would be reduced to around £750; and if it were two metres higher, the average loss would be reduced to only £20.

If no action is taken
With sea-level rise, the standard of protection afforded by present-day defences would be reduced from 1-in-100 years, to about 1-in-30 years. This is equivalent to an increase of 120% in future average losses and an 8% increase in the extreme 1-in-200 year loss compared with the present.

IF FLOOD DEFENCES ARE RAISED OR ENHANCED
If the flood defences are raised by only 30cm (ie maintaining the standard of protection of defences at 1-in-100 years future), average losses will increase by only 10% due to sea-level rise. For an extreme event with a return period of 1-in-200 years, raising flood defences by this amount will have no positive impact and defences will still be overtopped.

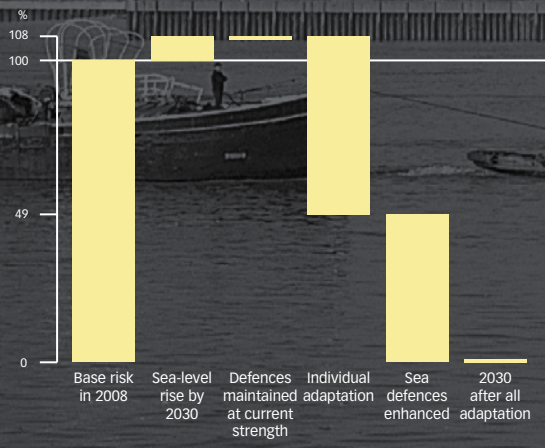
If the flood defences are enhanced at 1-in-250 years, future average losses are reduced by almost three quarters. With our simplified assumptions, the 1-in-200 year loss is reduced to zero, though in a real situation there would be some risk of failure of the defence.

IF THE PROPERTY IS ADAPTED WITH FLOOD RESILIENT AND FLOOD RESISTANT MEASURES
In the second approach, the property is adapted by installing measures offering a higher level of flood resilience and resistance (eg dry flood proofing). These upgrades will dramatically affect losses from storm surges under future sea-level rise.

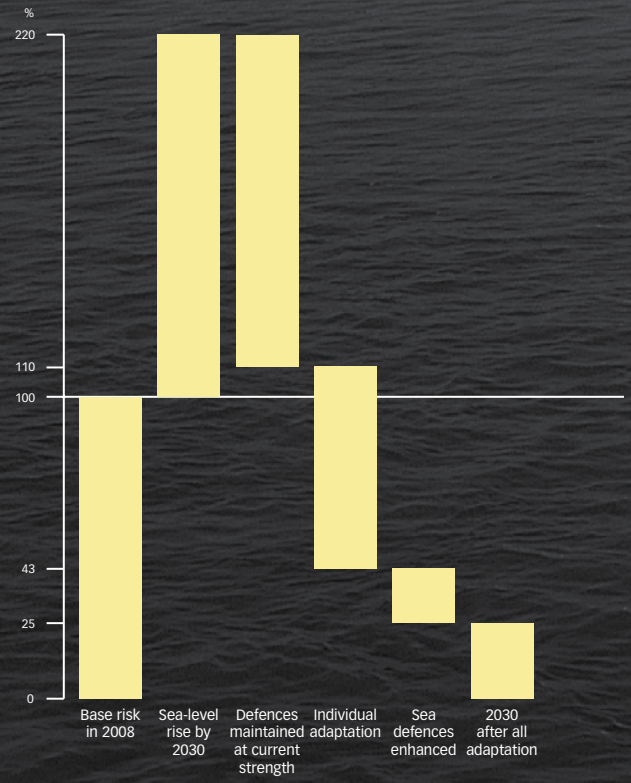
Assuming that large-scale flood defences are maintained at the current levels of 1-in-100 years, this action will reduce future average losses significantly, and could reduce them to less than half of existing levels.

CONCLUSIONS FROM THIS CASE STUDY
- In just over two decades, a high-risk property along a north European coast could be exposed to a doubling of average losses if measures to adapt are not taken, based on a 30cm increase in sea-level rise in that period.
- Sea flood defences could be enhanced to substantially reduce average losses, but they would not provide protection against very extreme events.
- Adapting properties to make them more resilient and resistant to damage by flood waters reduces the risk of both average losses and losses due to very extreme events.
- In this case study, we find that the installation of individual flood resilient and flood resistant measures have greater benefits (in terms of both average losses and losses from extreme events) than the enhancement of defences from a 1-in-100 year to a 1-in-200 year standard of protection. This finding is dependent on the assumptions made in this example and so can not be generalised. Any planning decisions must take into account local circumstances and must be informed by a risk-based cost-benefit analysis. However, in general, sea defences and individual measures are not either/or solutions and future planning should approach them as complementary.

Effect on 1-in-200 loss



Effect on average loss



CASE STUDIES
UNDEFENDED NORTHERN EUROPEAN COAST

This example uses the same type of property as the previous example, but situated in a slightly less exposed location where no flood defences exist. The study assumes that the property experiences some flood damage from a 1-in-25 year flood event, and significant flood damage from a 1-in-50 year flood event. It would be unusual for a property in a Northern European town to be exposed to such high risk; this example is representative of a rural residential property, farm or business situated on a coast.

As with the previous example, the frequency and intensity of storms that cause surges are assumed to remain unaltered by climate change. The impact of a 30cm rise in sea level has been tested. In this example, the loss-reduction benefits of introducing flood defences (to a 1-in-250 year standard of protection) and/or using flood resilient/resistant measures are investigated.

RESULTS

Present-day risk
If this property has a total insured value of £180,000 it would expect to experience average losses of just under £5,000 per year.

If no action is taken
Sea-level rise increases the average future losses by more than 75% by the 2030s, while extreme 1-in-200 year losses would rise by just over 10%. This increase in average loss would be less than in the example of a defended coastline. This is because losses in this case are already high (whereas in the example of the protected coastline, climate change will result in a threshold effect because some of the rare storm surges will begin to overtop the defences more frequently).

IF FLOOD DEFENCES ARE INTRODUCED
Future average losses are reduced by 90% of the value recorded for the undefended property in the 2030s, and by almost 80% compared with present-day losses. In this case, the introduction of flood defences would compensate for the projected sea-level rise on an average loss basis, as they would reduce future risk to below present-day levels.

It should be noted that the introduction of flood defences would do little to defend against extreme (low-frequency) storm surge events (ie those greater than the design standard of protection of the defence). In this case, we assume that overtopping of the defences would lead to complete failure.

IF THE PROPERTY IS ADAPTED WITH FLOOD RESILIENT AND FLOOD RESISTANT OPTIONS
Each of these measures alone results in a significant reduction in future average losses in current-day conditions, ranging from about 10% for reinforced cladding to almost 40% for a successful temporary flood wall constructed around the property. Substantial reductions are also achieved for the extreme 1-in-200 year loss, ranging from just over 10% for protection of mechanical and electrical equipment, to more than 30% for a temporary flood wall.

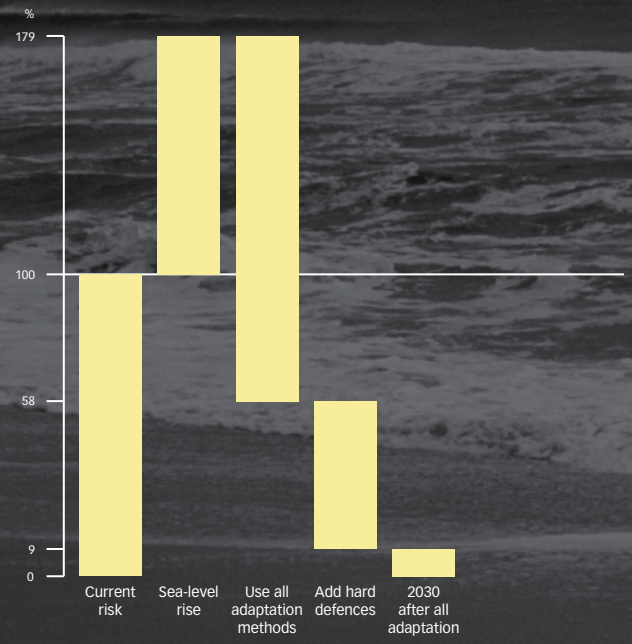
Under current conditions, when all of these measures are combined, future average losses are reduced by nearly 70% and losses from extreme 1-in-200 year events fall by more than 60%. When this combination of measures is applied to a property in the 2030s to give protection against sea level rise, future average annual losses are reduced by just over 40% below present-day levels. This is less than what can be achieved by flood defences alone, but is still significant.

IF A COMBINATION OF INDIVIDUAL RESILIENCE AND FLOOD DEFENCES ARE USED
The most significant impact is achieved by introducing both flood defences and combined flood resilient property characteristics, with future average losses lowered by about 90% compared to present day levels.

CONCLUSIONS FROM THIS CASE STUDY

- In just over two decades, if no action is taken, sea-level rise of 30cm could result in a property along a North European coast that is not protected by sea flood defences being exposed to future average losses more than 75% higher than present-day levels.
- The construction of sea flood walls in this undefended coastal example would have significant benefits. The introduction of defences with a 1-in-250-year standard of protection could reduce future average losses by about 90%, or, just over 20% of today's levels.
- A combination of individual measures (in the absence of flood defences) to make the property more resilient and resistant to damage by flood waters could reduce future average losses today by about 70%, and would also decrease losses from very extreme events.
- Future average losses could be reduced by 95% if sea flood defences are constructed and the property is adapted to make it more resilient and resistant to flood damage, to be just 10% above today's levels.

Effect of average loss



Flood loss reduction by adaption method

CASE STUDIES
COASTAL CITY IN SOUTHEAST ASIA

The previous three case studies explored the impact of climate change on storm-surge flood risk for coastal properties. However, climate change is only one of many factors expected to influence flood risk in coastal cities over the coming decades. Here, we look at the effect of urbanisation on rain-driven flood risk in a coastal city in Southeast Asia.

Urbanisation has a major impact on flood risk in many coastal locations, particularly in developing Asian cities, where rapid population growth can outpace flood management. It can also reduce the natural drainage qualities of the land and increase flood risk. This is an important factor driving increased flood risk from rivers in coastal cities such as Mumbai and Jakarta.

This example uses data for Jakarta – a city in which human activities are increasing the risk of both coastal and river flooding. Research suggests that peak discharge along the Ciliwung River increased by 150% between 1990 and 2002 due to urbanisation, leading to more frequent flooding of the city. By 2012, peak discharge is expected to increase by a further 20%.

Using a simplified model, this example investigates how urbanisation alone will affect flood risk in 2012 for an individual commercial property close to the river. The example also explores the loss reduction benefits of the same flood resilient and flood resistant measures that were examined in the last case study.

RESULTS

If no action is taken

Urbanisation alone could increase future average extreme losses by about 30% by 2012, compared with 2002, while losses from 1-in-200 events would rise by about 2%. The potential impact over this short period of time is comparable, when extrapolated, to the impact of sea-level rises which were outlined in the previous three case studies. This shows that the impact of climate change must be considered alongside other changes caused by human activity.

ADAPTING THE PROPERTY WITH SOME FLOOD RESILIENT OPTIONS

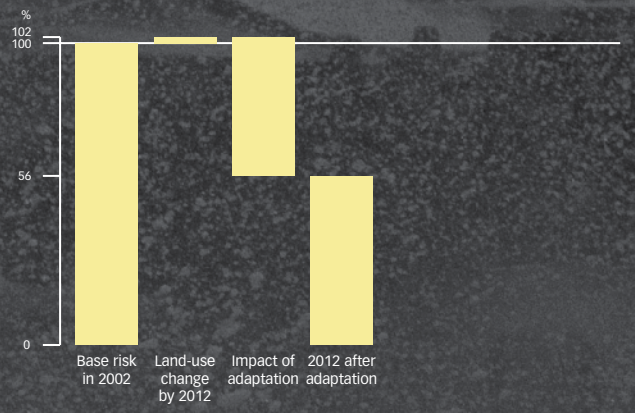
This could have a dramatic impact on future average losses. In comparison with an existing property in 2012, loss reductions range from about 15% for the protection of mechanical and electrical equipment to almost 35% for a temporary flood wall constructed around the individual property.

When all flood resilient and flood resistant characteristics are combined, future average losses are reduced by about 65%, compared with the unadapted building in 2012, and losses from extreme 1-in-200 year events are about 45% lower. The combined flood resilient property characteristics reduce losses in 2012 to a level that is significantly below the average losses for 2002.

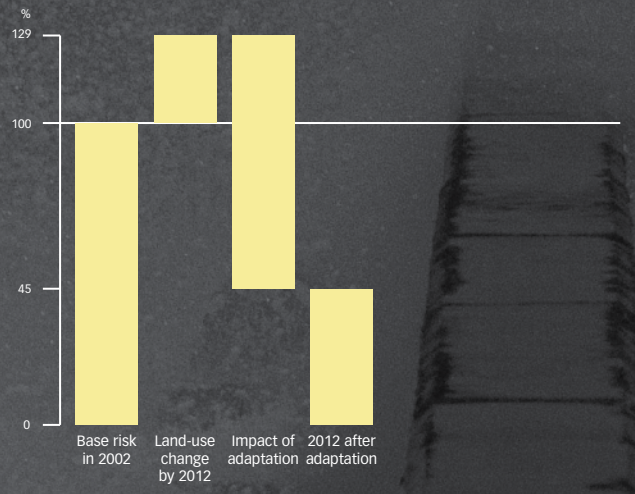
CONCLUSIONS FROM THIS CASE STUDY

- Progressive urbanisation in coastal areas of Southeast Asia will increase the run-off into rivers, and therefore, the risk of flooding. Average losses could rise by about 30% over a ten-year period for a highly exposed property.
- Adapting a property to make it more resilient and resistant to damage could reduce the future average losses from increased river flooding by about 65%.
- A combination of measures to make the property more resilient and resistant to flooding could reduce losses in the future to well below current levels, even if the hazard increases due to higher run-off from progressive urbanisation.
- Society must recognise that the cost of adaptation is a particular issue for the developing world and future planning must take this into account.

Effect on 1-in-200 loss



Effect on average loss



CONCLUSIONS

1 ADAPTATION IS KEY TO ENSURING FUTURE INSURABILITY

Risks arising from natural catastrophes are insurable but adaptation measures are vital to maintain the availability of affordable insurance for existing coastal properties. Adaptation methods include elevating properties, reinforced cladding and flood defences such as sea walls. No single approach provides full protection against all losses, and combinations of adaptation measures are essential to provide maximum protection levels. However, there is a cost attached to adaptation which governments and policyholders must consider. Individuals and businesses may need incentives to take adaptation seriously.

2 SOCIETY, BUSINESS AND THE INSURANCE INDUSTRY MUST BE FLEXIBLE IN THEIR RESPONSE TO CLIMATE CHANGE

Climate change projections are uncertain and a wide range of scenarios should be considered when planning for the future. Climate change models must be constantly updated to reflect evolving scientific information and society should build them into adaptation decisions.

3 HOUSEHOLD AND BUSINESS PROPERTY VALUATIONS SHOULD TAKE ACCOUNT OF LEVELS OF FUTURE RISK

A property which has been adapted is more valuable than one that hasn't because the risks for the home or business owner are reduced. In some areas where defences are not introduced or maintained, properties could lose value if they are uninsurable, and the withdrawal of private insurance coverage could be followed eventually by a 'managed retreat' from the highest risk areas by property-owners.

4 THE INSURANCE INDUSTRY HAS A KEY ROLE TO PLAY IN PROMOTING ADAPTATION

By setting premiums at a level which reflects the underlying risk, insurers promote the concept of risk-based pricing and enable individuals to understand their risk profiles better, and the costs and benefits of investing in adaptation components. Multiple-year policies have been suggested as a way to stabilise insurance costs for homeowners in coastal areas. However, given uncertainties about future climate change, it is unlikely that offering multiple-year insurance policies would be appropriate.

5 BETTER QUALITY DATA WILL HELP THE INSURANCE INDUSTRY TO CONDUCT MORE ACCURATE RISK ANALYSIS

All parties involved in the insurance chain must drive for much improved data quality and geographical resolution in order to allow full and proper risk analysis. As the intermediary between (re)insurers and buyers, brokers have an important part to play.

6 CLIMATE CHANGE IS ONLY ONE OF SEVERAL EMERGING TRENDS DRIVING FLOOD RISK

Socio-demographic factors such as global population increases, and the growth of mega-cities often combine with climate change to exacerbate risk. Adaptation strategies must not be developed in isolation from these factors and must take account of them.

ABOUT THE 360 RISK PROJECT

Today's risk environment is changing and evolving more rapidly than ever before. At Lloyd's, understanding and anticipating major risk trends is what we have been doing for 300 years.

Lloyd's 360 risk project was created with one aim: to generate discussion on how to manage risk in today's business environment. By tapping into the concentrated expertise and knowledge within the Lloyd's market, and bringing together the views of experts from the insurance industry and the wider business, political and academic worlds, we want to stimulate practical, thought-provoking discussion about the risk issues that matter, from climate change and terrorism through to corporate liability. Lloyd's 360 risk project will not give all the answers, but it will provide a forum for us to debate the steps we need to take to better manage risk.

To find out more about the 360 risk project and download the reports described below, visit www.lloyds.com/360. To request printed versions email 360@lloyds.com

ADAPT OR BUST

Explores what climate change could mean in our lifetime in four areas of particular relevance to the insurance industry: sea level rise, melting ice caps, flood and drought.

HOME-GROWN TERRORISM - WHAT DOES IT MEAN FOR BUSINESS?

Identifies the practical steps which companies must undertake to mitigate and manage risk of home-grown terrorism.

WHAT NEXT ON CLIMATE CHANGE?

Highlights the key issues raised during the 360 Live Debate on Climate Change and provides an update on how Lloyd's is addressing the issue of climate change.

TERRORISM IN ASIA - WHAT DOES IT MEAN FOR BUSINESS

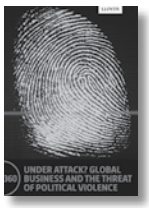
Examines the current terrorist threat in Asia, and how it impacts on business.

RAPID CLIMATE CHANGE

Addresses the issues and impact of climate change and the steps the insurance industry might take to prepare for the increasing volatility of the climate.

DIRECTORS IN THE DOCK - IS BUSINESS FACING A LIABILITY CRISIS?

Explores the growing litigation issues businesses are facing today.



UNDER ATTACK? GLOBAL BUSINESS AND THE THREAT OF POLITICAL VIOLENCE

Provides a corporate perspective on political violence and examines how geopolitical risk can impact business.

Since merchants first met to insure their ships at Edward Lloyd's coffee shop over 300 years ago, nearly every aspect of the way we do business has changed. But one constant is the bold confidence proclaimed by our motto, reflected in both our unique appetite for risk and our worldwide reputation for settling valid claims.

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