2018 RESILIENCE INDEX **METHODOLOGY**

pentland ANALYTICS

FM Global

SECTION 1

THE FACTORS OF RESILIENCE

The risk of disruption to a company's operations is a complex exposure, subject to many different influences. The process of identifying for an index a set of core drivers with significant impact on enterprise resilience to disruptive events is partly heuristic, partly statistical and partly practical.

Research into the causes of operational disruption and the drivers of recovery highlights some common themes. Conflict and political unrest, terrorism, corruption, vulnerability to oil shortages and price shocks, natural disasters, extreme weather, rapid urbanization, maturity and investment in risk management, infrastructure, and the quality of local suppliers all appear regularly. Increasingly, cyber risk and supply chain visibility also loom large.

To meet statistical criteria, the drivers of the index must demonstrably have an impact on resilience; represent faithfully the intended property; have sufficient sensitivity to detect changes in resilience, but not so much volatility as to disrupt the index; exhibit minimal correlation across drivers; and be calculated consistently (over a period of time to allow back-testing).

Practical considerations require that the data are available, quantitative (or quantifiable), global, annual and from credible sources.

Twelve core drivers of resilience have been selected for inclusion in the FM Global Resilience Index. These drivers are categorized as pertaining to economic, risk quality or supply chain factors, and are summarized below.

1. **Economic** – This factor represents political and macroeconomic influences on resilience. Combining to form this factor are four drivers: productivity, political risk, oil intensity and urbanization rate. Terrorism was found to be highly correlated with political instability, so these two variables are combined into a single driver: political risk.
2. **Risk quality** – A unique attribute of the FM Global Resilience Index is its ability to draw upon the wealth of experience and data gathered over many years by FM Global's team of property risk engineers who visit and assess more than 100,000 locations annually across the world. The metrics have the advantage of being applied consistently across all industry sectors and regions. This factor comprises three drivers sourced from FM Global: exposure to natural hazards, natural hazard risk quality and fire risk quality. An additional fourth driver is included to capture the inherent cyber risk of a country.
3. **Supply chain** – This comprises four drivers: control ofcorruption, quality of infrastructure, local supplier quality and supply chain visibility.

Provided in Section 2 is an overview of the FM Global Resilience Index structure and construction.
Full technical data definitions are provided in Section 3.

SECTION 2

THE INDEX STRUCTURE

Described in this section are the structure and construction of the FM Global Resilience Index. There are three levels to the index, as referenced in Table 1:

1. Level I provides a country ranking of enterprise resilience to disruptive events. Level I is an equally weighted composite measure of the three factors in Level II.
2. Level II comprises three factors, the core elements of resilience: economic, risk quality and supply chain. Each factor in Level II is an equally weighted composite of its respective drivers in Level III.
3. Level III includes a set of 12 drivers that determine the enterprise resilience to disruptive events for a country. Each driver measures a different aspect of resilience.

Table 1. The index structure

I. INDEX	THE FM GLOBAL RESILIENCE INDEX		
II. FACTORS	ECONOMIC	RISK QUALITY	SUPPLY CHAIN
III. DRIVERS	Productivity	Exposure to Natural Hazards	Control of Corruption
	Political Risk	Natural Hazard Risk Quality	Quality of Infrastructure
	Oil Intensity	Fire Risk Quality	Local Supplier Quality
	Urbanization Rate	Inherent Cyber Risk	Supply Chain Visibility

The index combines equally the 12 core drivers of resilience and provides ranked scores for 130 countries and territories around the world. Selected for inclusion are the largest countries (by gross domestic product) with the most complete set of data across the most recent five years.

The structure of the index enables business executives to identify the sources of strength and vulnerability in a country's resilience, both broadly across factors (economic, risk quality or supply chain), and more precisely across the 12 drivers. Such analysis offers opportunities to managers seeking to improve their company's resilience to disruptive events.

THE INDEX CONSTRUCTION

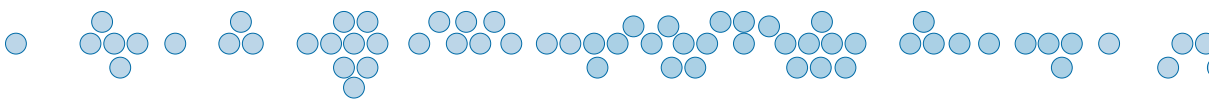
Described below are the key procedures applied to construct the FM Global Resilience Index from the underpinning data.

1. Annual data, for the most recent five years, are collected for the maximum number of countries and territories for each of the 12 drivers.
2. A common set of countries and territories with complete data availability across the 12 drivers is identified and aligned into a consistent data set.
3. Each data series is standardized through the calculation of z-scores to enable comparison and combination of drivers with different units. Where necessary, z-scores are inverted for consistency across variables.
4. The z-scores are converted into scores on a scale of 0 – 100 for presentation purposes.
5. The scores of the 12 drivers are combined with equal weighting to form the index.
6. The index comprises the rankings for the top 130 countries and territories for which data are available. Three regions are provided for each of China and the United States because their geographical spread includes disparate exposures to natural hazards, such as wind, flood and earthquake.

Based on data availability, new entrants to and exits from the index may emerge. In order to maintain consistency in the interpretation of results, the index is restricted to the top 130 countries and territories in any given year.

Many simulations were carried out to determine the most appropriate weighting scheme. Ultimately, very little difference emerged in the rankings from the adoption of various weighting schemes, so rather than impose a subjective system of aggregation without good reason to do so, it is appropriate to remain with equal weights across the 12 core drivers of resilience.

The overall composite index is, by design, a simplified, summary measure of resilience. The FM Global Resilience Index provides an indication of countries' relative enterprise resilience to disruptive events. In combination with additional information, this provides business executives with a source of guidance on enterprise risk when making decisions about risk improvement priorities, sourcing suppliers or the destination of physical investments.



SECTION 3

SOURCES AND DEFINITIONS

Provided in this section is the technical definition of each index driver and its data source.

TABLE 2. Definitions and data sources

ECONOMIC		
PRODUCTIVITY	Gross domestic product (GDP) based on purchasing power parity, divided by total population	International Monetary Fund (IMF)
POLITICAL RISK	The perceived likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically motivated violence and terrorism	World Bank
OIL INTENSITY	Vulnerability to an oil shock (shortage, disruption, price hike); oil consumption divided by GDP; measures dependency on oil for productivity	U.S. Energy Information Administration
URBANIZATION RATE	The average annual rate of change in the extent to which a country's population is living in an urban area	United Nations (UN)
RISK QUALITY		
EXPOSURE TO NATURAL HAZARDS	The percentage of a country's area devoted to economic activities that is exposed to at least one natural hazard: wind, flood or earthquake	FM Global
NATURAL HAZARD RISK QUALITY	The quality and enforcement of a country's building code with respect to natural hazard-resistant design (80%), combined with the level of natural hazard risk improvement achieved, given the inherent natural hazard risks in a country (20%)	FM Global
FIRE RISK QUALITY	The quality and enforcement of a country's building code with respect to fire-based design (80%), combined with the level of fire risk improvement achieved, given the inherent fire risks in a country (20%)	FM Global
INHERENT CYBER RISK	Vulnerability to a cyber attack combined equally with the country's ability to recover; captured by internet penetration (the percentage of individuals in a country who have access to the internet) and civil liberties	UN and Freedom House, respectively
SUPPLY CHAIN		
CONTROL OF CORRUPTION	The perceived extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as capture of the state by elites and private interests	World Bank
QUALITY OF INFRASTRUCTURE	The perceived quality of general infrastructure: transport, telephony and energy	World Economic Forum (WEF)
LOCAL SUPPLIER QUALITY	The perceived quality of local suppliers	WEF
SUPPLY CHAIN VISIBILITY	The ability to track and trace consignments across a country's supply chain	World Bank

Data on political risk (political stability and absence of violence or terrorism) and control of corruption are obtained from the Worldwide Governance Indicators (WGI) data set from the World Bank. The WGI comprise information from 31 existing data sources that report the views and experiences of citizens, entrepreneurs and experts in the public, private and non-governmental organization (NGO) sectors from around the world, on the quality of various aspects of governance. Data on supply chain visibility also are sourced from the World Bank, specifically from its Logistics Performance Index (LPI). The data are obtained by a survey of global freight forwarders and express carriers who provide feedback on the logistics attractiveness of the countries in which they operate, and with which they trade.

Data on infrastructure and local supplier quality are obtained from the Global Competitiveness Report produced annually by the WEF. The data are based on the WEF's annual Executive Opinion Survey which garners regularly over 14,000 responses.

The data for three of the risk quality drivers are provided by FM Global, one of the world's largest commercial and industrial property insurers. Further detail on their compilation is provided below.

1. **Exposure to natural hazard** – FM Global property risk engineers determine whether any natural hazard exposures are present at the locations they visit. The determination is based on wind, flood and earthquake maps, populated areas defined by satellite-based night lights, and additional information acquired by engineers. The percentage of the country's area devoted to economic activities that is exposed to at least one natural hazard peril (earthquake, wind, or coastal or riverine flood) is summarized for each country.

   Exposed areas are determined based on potential losses from 100-year wind gusts greater than 100 mph (161 kph), water flowing from rivers in 100-year flood zones, or more frequent than 500-year earthquake motions that can cause damage to weak systems.

   China and the United States are each divided into three regions to accommodate for a significantly different dominant natural hazard exposure within these countries. Regions in the United States are based on states, and regions in China are based on provinces, municipalities and autonomous regions. The composition of each region is provided in Section 5.

2. **Natural hazard risk quality** – To capture the quality of a country's management of natural hazard risks, two components are combined. Dominant (and weighted 80 percent) is a measure of the quality and enforcement of a country's building code with respect to natural hazard-resistant design. A full exposition of the building code rating methodology is provided in Section 4. The remaining component (weighted 20 percent) reflects the risk quality of actual facilities and is obtained from FM Global's proprietary Risk*Mark*® database available to FM Global clients.

Risk*Mark* is a benchmarking algorithm that calculates the risk quality of FM Global's insured locations. It uses a 100-point scale (100 representing the best managed, highest-quality risk), and the scale comprises the following four components:

i. Fire Hazards and Equipment Hazards: 36 points
ii. Natural Hazards: 30 points
iii. Human Element and Other Factors: 19 points
iv. Inherent Occupancy Hazards: 15 points

The Risk*Mark* score of a location includes a measure of both inherent risks and risks where there are recommendations for improvement. The potential Risk*Mark* score represents the highest possible score achievable by that location, given those inherent risks. The percentage potential Risk*Mark* score provides a way to measure risk improvement opportunities given the inherent risks. It is calculated by dividing the Risk*Mark* score by the potential Risk*Mark* score.

For the risk quality driver, natural hazard risk quality, the weighted average (by total insured value) percentage potential Risk*Mark* score for the natural hazard component is provided for each country or region where there is a statistically sufficient number of locations. Those countries with few locations are rated solely by the quality and enforcement of the country's building code with respect to natural hazard-resistant design.

3. **Fire risk quality** – For this risk quality driver, fire risk quality, the same logic as natural hazard applies. The quality of a country's management of fire risk combines two components: a measure of the quality and enforcement of a country's building code with respect to fire-based design (weighted 80 percent), and a measure of the fire risk quality of actual facilities visited by FM Global property risk engineers.

   For this metric, the weighted average (by total insured value) percentage potential Risk*Mark* score for the fire subcomponent of the fire and equipment hazards component is provided for each country or region where there is a statistically sufficient number of locations. Again, those countries with few locations are rated solely by the quality and enforcement of the country's building code with respect to fire-based design.

   The fourth risk quality driver, inherent cyber risk, combines equally a country's vulnerability to cyber attack with the country's ability to recover from such an attack. The former is captured by a measure of internet penetration, using data sourced from the International Telecommunications Union (ITU), a division of the UN. To reflect a country's ability to help businesses heal and recover from a cyber attack, a measure of civil liberties is used, combining freedoms of expression, assembly, association, education and religion, and an established and fair legal system that ensures the rule of law, allows free economic activity, and strives for equal opportunities for all. The data are sourced from Freedom House, a nonprofit watchdog organization.

SECTION 4

Described in this section is the method by which FM Global property risk engineers estimated the quality of building codes around the world with respect to natural hazard and fire risks. Evaluation of the outcome of building codes and regulations entails a method that is based not only on the requirements of the code but also on the level of its enforcement. The approach adopted combines an understanding of the requirements with actual observations by FM Global property risk engineers in the field.

BUILDING CODE RATING METHODOLOGY

1. National building codes and their implementation were reviewed first in order to define the key questions for a survey that would yield the most, and most relevant, responses.

2. Based on this review, and following a pilot study, the following filter questions were established to address natural hazard and fire risk, respectively:
   a. Is there a regularly used and updated building code that includes mandatory requirements for natural hazard-resistant designs published in the country?
   b. Is there a regularly used and updated building code that includes mandatory requirements for fire-based design published in the country?

3. To ensure that requirements are fully understood, they need to be adopted fully and within the mainstream of building practice in a country. A revised code or draft code would not meet these criteria. A code quality score of 2 was assigned for observed full code covering natural hazard/fire elements, 1 for limited code covering these elements, and 0 where these elements are absent.
   a. In the case of natural hazards, matching design requirements for seismic, wind, snow, etc., were considered.
   b. In the case of fire risk, requirements covering fire-rated compartmentation, fire protection, combustibility requirements for materials, etc., were considered.

4. As noted, the presence of strong enforcement will ensure that the outcome of a code is delivered. Therefore, for each natural hazard and fire risk, the following contingency question was asked: Are these requirements regularly enforced?

5. The focus is placed on what is observed in a country rather than what is intended, and responses to the question of enforcement concentrate on the skill, education and training available to implement the requirements regularly. A code enforcement score of 2 was assigned for observed strong and consistent enforcement, 1 for limited enforcement, and 0 for negligible or poor enforcement. The code enforcement score is applied as a multiplier to the code quality score, reflecting the practical power of effective code enforcement.

6. A final modifier was added to the resultant score (quality x enforcement) to introduce the observed availability of flood maps into the natural hazard elements and the requirements for automatic sprinkler protection into the fire elements.
   a. There are limited elements within building codes with respect to flood hazard. Usually, it is considered in the wider elements of building laws relating to development and land use that determine where a building can be sited. However, this requires a scheme of flood maps to assess the risk. A score of 1 is added if nationally recognized flood maps are present and available in the country.
   b. FM Global's experience shows that a key driver in minimizing fire damage is the presence of automatic sprinkler protection. In the industrial arena, the typical target occupancies are offices, warehouses and factories, in particular, buildings of moderate size at 5,000 square meters. Such buildings represent a reasonable scale of investment where fire protection makes economic sense based on value alone in most territories. A score of 1 is added if there is a requirement for the installation of automatic sprinklers within this size of building in any of the specified occupancies.

TABLE 3. Survey structure

NATURAL HAZARD ELEMENTS	SCORE
Is there a regularly used and updated building code that includes mandatory requirements for natural hazard-resistant designs published?	0, 1, 2
Are these requirements regularly enforced?	0, 1
Are there current, nationally recognized flood maps available?	0, 1
FIRE ELEMENTS	**SCORE**
Is there a regularly used and updated building code that includes mandatory requirements for fire-based design published in the country?	0, 1, 2
Are these requirements regularly enforced?	0, 1, 2
Based on a 5,000-m^2 building, would the code require automatic sprinklers to be installed in any of office/warehouse/factory buildings?	0, 1

7. The questions were distributed to FM Global property risk engineers who were surveyed and interviewed for their expert assessment of building code quality and enforcement, based on their actual observations in the field.
8. For those countries where limited observations were available, secondary research in the form of a literature review of the available code was used to supplement the primary field research.
9. Finally, the ratings were reviewed iteratively by the engineering and standards community to ensure consistency in grading, and to reach consensus on the relative ratings.

The FM Global engineering team operates across the world, visiting industrial and commercial clients to undertake property risk evaluations. The engineers apply their training and assess the current conditions to the applicable FM Global standards in order to determine if there are opportunities to enhance the protection of a facility against natural hazard and fire risks. Through this work, FM Global engineers enjoy unique access to observe the practice and application of building codes and regulations across different countries.

SECTION 5

COUNTRY REGIONS BY DOMINANT NATURAL HAZARD

TABLE 4.

CHINA 1	CHINA 2	CHINA 3	UNITED STATES 1	UNITED STATES 2	UNITED STATES 3
Wind	**Earthquake**	**Miscellaneous**	**Wind**	**Earthquake**	**Miscellaneous**
Fujian	Hebei	Anhui	Alabama	Alaska	Arizona
Guangdong	Jiangsu	Beijing	Connecticut	California	Arkansas
Hainan	Neimenggu	Chongqing	Delaware	Hawaii	Colorado
Jilin	Ningxia	Gansu	Florida	Nevada	District of Columbia
Liaoning	Sichuan	Guangxi	Georgia	Oregon	Idaho
Shandong	Tianjin	Guizhou	Louisiana	Puerto Rico	Illinois
Shanghai	Yunnan	Heilongjiang	Maine	Utah	Indiana
Zhejiang		Henan	Maryland	Washington	Iowa
		Hubei	Massachusetts		Kansas
		Hunan	Mississippi		Kentucky
		Jiangxi	New Hampshire		Michigan
		Qinghai	New Jersey		Minnesota
		Shaanxi (Shanxi)	New York		Missouri
		Xinjiang	North Carolina		Montana
			Rhode Island		Nebraska
			South Carolina		New Mexico
			Texas		North Dakota
			Virgin Islands		Ohio
			Virginia		Oklahoma
					Pennsylvania
					South Dakota
					Tennessee
					Vermont
					West Virginia
					Wisconsin
					Wyoming

ABOUT **FM GLOBAL**

Established nearly two centuries ago, FM Global is a mutual insurance company whose capital, scientific research capability and engineering expertise are solely dedicated to property risk management and the resilience of its client-owners. These owners, who share the belief that the majority of property loss is preventable, represent many of the world's largest organizations, including one of every three Fortune 1000 companies. They work with FM Global to better understand the hazards that can impact their business continuity in order to make cost-effective risk management decisions, combining property loss prevention with insurance protection.

fmglobal.com

ABOUT **PENTLAND ANALYTICS**

Pentland Analytics provides advanced analytics and advisory services to the executive management of the world's leading companies. The firm converts complex business issues into innovative analytics solutions that yield new insights and direction. Core services include devising algorithms that serve to help clients build resilience, reputation and shareholder value; establishing thought leadership on strategic topics of commercial interest; and translating complex analytics into clear recommendations.

pentlandanalytics.com

pentland ANALYTICS

FM Global®