R7 - Internal report on Bayesian Risk Assessment & Management Model Development V1.0

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1 Introduction

During the execution of the R7 and R13 (U.S.-Mexico risk Taskforce to support the health supply chain systems for infrastructure and workforce threatened by the COVID-19 pandemic), a series of sources of evidence were identified to support the key groups of variables and processes depicted in [1]. From these, the Bayesian Network (BN) model was updated to capture variables/processes present on sources of evidence such as:

- CDC's Social Vulnerability Index [2]
- Census's Community Resilience Estimates [3]
- Mexico's COVID-19 Social Vulnerability Index [4]
- Mexico's Heuristic COVID-19 Mortality Risk
- Impact of Natural Threats on Supply Chains

The updates on different components of the model are listed below:

- Natural threats: *Hail, Sleet, Atmospheric temperature, Soil physical properties, soil mechanical properties, Tsunami*, and *Runoff* were included
- Anthropogenic Threats: *Unemployment*, and *Income* were included as variables
- Vulnerable Systems: New subgroups of variables were introduced to capture the social vulnerability of a community across different dimensions such as housing and transportation, socioeconomic status, minority status, and language
- Vulnerable Systems: *Public Hospitals, Private Hospitals, Public Intensive Care Unit (ICU) Beds, Private Intensive Care Unit (ICU) Beds, Public Non-ICU Beds, Private Non-ICU Beds* were added as variables on the Health System Services group of variables.
- States of Risk: *Socioeconomic* states of risk for *State of Income*, *State of Unemployment*, and *State of Poverty* were included in the model to reflect an estimate of this variables in communities.

The updated model became V1.0 of the BN Risk Assessment and Management model (CBTS-RAM). Appendix 2 includes a High-res PDF version of the this model. This showed the successful collaboration between R7 and R13, where R7 expedited the identification of variables and processes relevant for the CBTS-RAM model, while providing guidance to R13 on the prioritization of variables.

2 Variable Definitions for Risk Assessment Model

2.1 Threats

2.1.1 Natural

Geological

Volcanic Activity: the likelihood of volcanic activity events such as emission of gases, non-explosive lava emissions to extremely violent explosive bursts [5].

Seismic Activity: measures earthquake likelihood, mechanisms, and magnitude for a given geographical location [6].

Elevation/Bathymetry: Elevation is the distance above sea level for a given location. Bathymetry is the ocean's depth below sea level for a given location [7].

Soil Physical Properties: include color, texture, structure, porosity, density, consistence, temperature, and air. [8].

Soil Mechanical Properties: include basic properties such as cohesion, and composite properties such as penetration resistance. [9]

Subsidence: The likelihood of sinking of the ground because of underground material movement. It is most often caused by the removal of water, oil, natural gas, or mineral resources out of the ground by pumping, fracking, or mining activities. [10].

Snow Avalanche: the likelihood of rapid flow of snow mass and ice on slopes, which can contain soils, rocks, and vegetation [11]. Snow avalanches are classified according to their destructive potential, mass, path length, and impact pressure [12].

Rockfall: the likelihood of a mass of rock from a bedrock on a steep slope is detached with a small or no shear displacement [13]. Rockfalls are characterized by slope height, geologic character, volume, climate, presence of water on slope, and rockfall history [14].

Debris Flow: the likelihood of a gravity-driven movement of sediments containing water as a mixture that flows fast or extremely fast [15]. Debris flow size can be classified based on total volume, peak discharge, and area inundated by debris [16].

Landslide: the likelihood of a downslope movement of a soil mass that occurs on a surface of rupture or on a relatively thin zone of intense shear strain. [17]. Slides are characterized

by material, mechanism, mass, and velocity among other parameters [18, 19].

Atmospheric

Pressure Distribution: distribution of atmospheric pressure that varies in terms of geographical location and season.

Humidity: amount of water vapor contained in the air that can be measured as vapor pressure, mixing ratio, or specific humidity [20].

Wind: it refers to wind velocity. Wind speeds can be classified by using the Beaufort Wind Scale [21].

Lightning: only cloud to ground lightning discharge is considered in this variable. The intensity of the discharge can be characterized by electric current, current duration, and voltage [22].

Cloud Cover: "total area of the sky nearest to the earth that is covered with clouds" [23]. Cloud cover can be measured in terms of "Okta" or one-eighth of the sky [23].

Sunlight: amount of sunlight reaching Earth's surface that is measured in units of watts per square meter [24].

Snowfall: accumulation of snow that is often measured by visibility, and by measuring liquid equivalent snowfall rate [25].

Surface Air Temperature: temperature measured at a standard height of 1.5 or 2 meters above the surface [26].

Surface Energy Balance: "sum of all fluxes of energy passing each second through a horizontal surface of unit area" [27]. Measured in Joules per second per square meter, or watts per square meter.

Rainfall: the intensity of rainfall is characterized by the average rainfall for a specific duration and frequency [28].

Greenhouse Gas Concentration: includes carbon dioxide, methane, nitrous oxide, and halogenated gases (chlorine, fluorine, or bromine). Concentrations of these gases are measured in parts per million (ppm), parts per billion (ppb), or parts per trillion (ppt) by volume [29].

Hurricane: "a rotating low-pressure weather system that has organized thunderstorms but no fronts (a boundary separating two air masses of different densities)" [30]. Hurricanes are classified based on their wind speed as suggested in the Saffir-Simpson Hurricane Wind Scale [31].

Vertical Wind Shear: change of winds' direction and velocity at increasing heights in the atmosphere [32].

Convective Available Potential Energy: "it describes the instabilily of the atmosphere and provides an approximation of updraft strength within a thunderstorm" [33]. CAPE is expressed in joules per kilogram and can range from zero to over 5000.

Tornado: "a violently rotating column of air touching the ground, usually attached to the base of a thunderstorm" [34]. Tornadoes are classified as "weak", "strong", or "violent" based on their estimated wind speeds and resultant damage according to the National Weather Service [34].

Atmospheric Temperature: The temperature of Earth's atmosphere varies with the distance from the equator (latitude) and height above the surface (altitude). It also changes with time, varying from season to season, and from day to night, as well as irregularly due to passing weather systems [35].

Hail: form of precipitation consisting of solid ice that forms inside thunderstorm updrafts [36].

Sleet: frozen raindrops that occur when the layer of freezing air along the surface is thicker. This causes the raindrops to freeze before reaching the ground. [37]

Oceanographic

Sea Level: refers to "Relative Sea Level", which is the height of the ocean with respect to land along a coastline for a given region or location [38].

Sea Surface Temperature: water temperature measurements taken at depths that range from 1 millimeter to 20 meters [39].

Surge: also known as "storm surge", which is the result of increased sea level due to a tropical or extratropical cyclone impacting a coast. Storm surge height depends on storm's forward speed, central pressure, angle of approach (relative to the coast), and the local topography and bathymetry [40].

Hydrological

Coastal Flooding: inundation of land areas along a coast as a consequence of sea level rise [41].

Inland Flooding: inundation of land as a consequence of moderate or intense rainfall over short or long periods respectively. [41].

Water Quality: "measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics" [42].

Tsunami: A disturbance in the water column forming long-wavelength waves which gain amplitude with decreasing water depth. Most of the destruction caused by a tsunami is caused by the retreat of subsequentially larger waves which can make landfall up to an hour apart [43].

Runoff: The portion of precipitation or snowmelt that does not infiltrate into the soil and instead runs downhill across the ground surface collecting in uncontrolled streams, rivers, drains, or sewers [44].

Biological

Insect Outbreak: the likelihood of "an explosive increase in the abundance of a particular specie of insects that occurs over a relatively short period of time" [45].

Vector Density: degree of concentration of vector population per area at a given time [46].

Stray and Feral Pet Population: domestic and non-domestic dogs and cats population for a specific location or region at a given time [47].

Reservoir Host Density (Animals): degree of concentration of infected animals from a pathogen per area at a given time [46].

Air Quality: the degree at which ambient air for a given location and time is pollution-free. The U.S. Environmental Protection Agency issued a national air quality index since 1976 that provides a daily air quality report by state [48].

Fauna Migration: the likelihood of movement of individual or group of animals as a consequence of a natural or anthropogenic threat [49].

Fire Regime: "the spatial and temporal pattern of fires and their effects in a given area and over a given time period" [50].

Soil/Ground

Drought: drought indices are employed to quantify meteorological, agricultural and hydrological droughts such as Rainfall Anomaly Index (RAI), Palmer Drought Severity Index (PDSI), Standardized Precipitation Index (SPI), Reconnaissance Drought Index (RDI), Standardized Precipitation Evapotranspiration Index (SPEI), Crop Moisture Index (CMI), Soil Moisture Drought Index (SMDI), and Standardized Runoff Index (SRI) [51].

2.1.2 Anthropogenic

Land use/Land cover

Land Cover: it measures how much area of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types [52].

Land/Wildlife Management: this variable represents the availability of governmental programs to preserve and improve habitats for a given location and time [52].

Governance and politics

Governance and Cultural Values: it represents the likelihood of how governance and cultural values can influence other anthropogenic processes such as corruption and political stability [49].

Political Stability: probability that a political system can cope a threat or a combination of threats in a given location and time [53].

Corruption: the likelihood of presence of corruption in a supply chain system [54].

Economic Activities

Child Labour: the likelihood of presence of child labour practices in a supply chain system [55].

Tourism: the likelihood of how tourism has an effect on the eating habits of a given region. Exotic eating habits can enable the emerge of parasites in food [47].

Herding: the likelihood of herding practices in a given time and location [47].

Hunting: the likelihood of hunting practices in a given time and location [47].

Occupations: the likelihood of diversity in terms of jobs and economic occupations for a given region. [47].

Population

Poverty: it is defined by a set of money income thresholds that vary by country, family size, and composition to determine the degree of poverty [56, 57].

Regional/Local Population: the degree of overpopulation for a given location and time [58].

Population Change: the degree of difference in size of population between two periods of time (e.g. monthly, yearly, etc.) [58].

Population Density: human population per unit area for a given location and time. [58].

Cultural Diversity: the likelihood of how cultural diversity has an effect on the eating habits of a given region. Exotic eating habits can enable the emerge of parasites in food [47].

People Displacement: movement of people from one place to another in order to avail themselves of opportunities, to make a better life and to avoid undesirable risks and harm [58].

Unemployment: civilian persons unemployed divided by total civilian population. Unemployed persons actively seeking work [2].

Income:The mean income computed for every person in a census tract [2].

Education & Knowledge

Scientific Knowledge: this variable aims to represent the degree of production of knowledge for a specific country or region at a given time. This can be measured by using qualitative and quantitative indexes such as the h-index, g-index, impact factor, etc. [59].

Traditional Indigenous Knowledge: "a network of knowledges, beliefs, and traditions intended to preserve, communicate, and contextualize Indigenous relationships with culture and landscape over time" [60].

Access to Education: the degree at which a population have access to formal education at a given location and time. This might be measured using proxies such as number of school institutions, teachers, students, etc. [61].

Education Level: this variable measures the distribution of the highest levels of education achieved in a community. The International Standard Classification of Education (ISCED) suggest 8 levels of education based on the complexity of educational content [62].

Misinformation: the degree of "information that is false or inaccurate, and not supported by scientific evidence" [63] that is produced in a given region and time.

Discrimination: the degree of racial discrimination activities or events for a given location and time [64].

Crime & Terrorism

Terrorism: the likelihood of terrorism activities defined as "the use of force or violence against persons or property in violation of the criminal laws of the United States for purposes of intimidation, coercion, or ransom" [65].

Crime & Violence: this variable can be characterized by country or regional level indicators such as rates of violent crime, incarceration, homicide, etc. [66].

Cyber Threats

Piracy: the likelihood of misuse of data outside the principal purpose of releasing data by the owner [67].

Cyber Attack: likelihood of an attack to IT infrastructure with the intention of corrupting or damaging data/information [68].

Information Theft: the likelihood of loss of control over sensitive information [67].

IT Failure: likelihood of a failure in the normal operation of IT networks, leading to unavailability of critical services [67].

Ecosystem Services

Water Security: the degree of how reliable is the access to "affordable and safe drinking water in adequate supply for basic needs" [69].

Water Supply: the degree of how reliable is the access to affordable and clean water to satisfy the needs of both health-care system and supply chain system [69].

Power Supply: it refers to the degree of supply of electric power for both health-care and supply chain systems [70].

Community Disposal Practices: it captures if garbage disposal practices are enforced or not in a community [47].

Human-Human COVID-19 Transmission

Infected Human Cases (SARS-CoV-2: number of infected human cases by SARS-CoV-2 for a given location and time [71].

Effective Reproduction Number R(t): average number of secondary cases per primary case at calendar time t [72].

COVID-19 Community Spread: the degree and likelihood of COVID-19 spread in a community for a given time [71].

Superspreader Events: refers to events where a large number of secondary cases relative to the standard reproductive rate, R_0, are initiated, thus acting as a catalyst for outbreaks. They can be classified as 'societal' or isolated' [73].

The following variables of the model are included as parent nodes for *Superspreader Events*. In the context of the model, they refer to the likelihood of a given event, situation, or activities in a mentioned location, to become a *superspreader event* [73]:

- *Migrant Caravan*
- *Migrant Detention Center*
- *Emergency Shelter*
- *School*
- *Religious*
- *Other Social Events*
- *Shopping*
- *Protests*
- *Transportation Vehicles*
- *Prison*
- *Restaurants/Bars*
- *Barracks*
- *Conference*
- *Sport Events*

Community Demographics: involves demographic characteristics such as income inequality, unemployment, health insurance, gender, and race. These characteristics are related to the rates of COVID-19 spread [74].

SARS-CoV-2 Mutation in Human Host: the likelihood of a new SARS-CoV-2 mutation in human hosts, and its infectivity intensity [75].

Direct Contact: Airborne: the likelihood of having a direct contact with SARS-CoV-2 via airborne for a given location and time [76].

Direct Contact: Respiratory Droplets: the likelihood of having a direct contact with SARS-CoV-2 via respiratory droplets for a given location and time [76].

Indirect Contact: Contaminated Surfaces (Indoor): the likelihood of having an indirect contact with SARS-CoV-2 via contaminated surfaces in an indoor location at a given time [77].

Indirect Contact: Contaminated Surfaces (Outdoor): the likelihood of having an indirect contact with SARS-CoV-2 via contaminated surfaces in an outdoor location at a given time [77].

Proximity (H-H): the likelihood and intensity of concentration of people for a given location and time. Mobility data from mobile devices, social media, and commercial air travel are useful to characterize this variable, and its effect on COVID-9 spread in a community [78].

2.1.3 Zoonotic Diseases Spillover

Human Infection

Emerging Zoonotic Disease Spillover: likelihood and intensity of a zoonotic disease spillover in a community at a given time [46].

Probability of Human Infection: probability of a human to be infected from a zoonotic disease [46].

Structural Barriers: physical barriers such as "skin, mucous membranes, mucus, stomach acid or the absence of functional receptors that enable the pathogen to enter its target cells or tissues" [46].

Innate Immune Response & Molecular Compatibility: protective mechanisms that include apoptosis or the induction of interferon-induced resistance in surrounding cells [46].

Human exposure due to excretion

Human Exposure dose due to Excretion: the likelihood and intensity of the exposure dose due to animal excretion for a given location and time [46].

Human Interaction with Reservoir Host: the likelihood of a human of being in contact with a pathogen reservoir host at a given location and time [47].

Probability that Pathogen from Excretion Disperses: the likelihood that excretions from infected animals disperse at a given location and time [46].

Duration of Pathogen Survival from Excretion: it measures how much time the pathogen from excretion survives [46].

Reservoir Host Excretion Rate: "rate at which pathogen is shed from a reservoir host" at a given location and time. [46].

Reservoir Excretion Intensity of Infection: the average intensity of infection from a reservoir host excretion [46].

Prevalence of Infection Among Reservoir Host (Animals): the likelihood of prevalence of infection among reservoir hosts at a given location and time [46].

Average Intensity of Infection on an Infected Reservoir Host: in average, the pathogen intensity of infection on infected animals at a given location and time [46].

Human exposure due to infected meat

Human Exposure Dose due to Infected Meat: the likelihood and intensity of the exposure dose due to infected meat for a given location and time [46].

Dose Exposure Associated to Harvesting Activity: the dose related to humans that are exposed to a pathogen infection due to harvesting of infected animals [46].

Dose Exposure Associated to Butchering and Preparation: the dose related to humans that are exposed to a pathogen infection due to butchering and preparation of infected meat [46].

Dose Exposure Associated to Eating: the dose related to humans that are exposed to a pathogen infection due to eating infected meat [46].

Duration of Pathogen Survival from Meat Harvested: it measures how much time the pathogen from infected meat survives [46].

Probability that the Meat Harvested will be Transported and Prepared or Consumed: the likelihood of infected meat will be transported, prepared or consumed at a given location and time [46].

Reservoir Host Harvest Rate: "rate at which reservoir hosts are harvested" at a given location and time [46].

Human exposure due to infected vector

Human Exposure Dose due to Infected Vector: the likelihood and intensity of the exposure dose due to infected vector for a given location and time [46].

Per-vector Rate of Biting Humans: total rate at which infected vectors bite humans at a given location and time [46].

Dose to which a Human is Exposed when Bitten by Infectious Vector: the dose related to humans that are exposed to a pathogen infection when bitten by infectious vector [46].

Duration of Pathogen Survival from Vector: it measures how much time the pathogen from an infected vector survives [46].

Probability that Pathogen from Infected Vector Disperses: the likelihood of pathogen dispersion from infected vectors at a given location and time [46].

Latent Period: "the period of time between the occurrence of infection and the onset of infectiousness (when the infected individual becomes infectious)" [79].

Infectious Period: the time interval during which a host is capable to transmit a pathogen directly or indirectly to another susceptible host [80].

Vector Competence: probability that an infected vector transmits a pathogen to humans [81].

Total Rate at which Uninfected Vectors Bite Reservoir Host: rate at which uninfected vectors bite reservoir hosts at a given location and time [46].

Probability that Vector becomes Infected: the likelihood of a vector to become infected by biting an infected animal [46].

2.2 Vulnerable Systems

2.2.1 Community Health

Social Vulnerability

Households Without Vehicle Estimate: number of households with no vehicle available [2].

Mobile Homes: number of mobile homes [2].

Houses With Dirt Floor: number of houses with dirt floor conditions [4].

Households Without Running Water: number of households without runing water [4].

Households Without Electricity: number of households without electricity [4].

Households Without Fridge: number of households without fridge [4].

Crowding: number of housing units with more than one person per room [2].

Households Without Toilette: number of households without toilette [4].

Households Without Public Drainage: number of households without public drainage [4].

Households Without Washer: number of households without washer [4].

Housing In Structures With More Than 10 Units: number of houses in structures with more than 10 units [2].

Lack of Adequate Nutrition: number of people with lack of adequate nutrition [4].

Housing and Transportation/Housing and Hygiene: aggregated index for housing, transportation, and hygiene variables [2].

Socioeconomic Status: aggregated index for education level, income, poverty, and unemployment variables [2].

Lack of Healthcare Access: number of people with lack of healthcare access [2].

Disability: number of people with a disability [2].

Age: the likelihood and distribution of age for a given population and time. [82].

Single, or Zero Parent Household: single, or zero parent household with children under 18 [2].

Household Composition and Disability: aggregated index for household composition and disability variables [2].

Ethnicity: the likelihood and distribution of race for a given population and time. [82].

Communication Barrier: number of persons (age 5+) who speak English "less than well"[2].

Minority Status and Language: all persons except white, non-Hispanic [2].

Social Vulnerability: overall aggregated index for social vulnerability variables [2].

Comorbidities

Chronic Diseases: group of "conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both" [83]. The model includes the following conditions: asthma, chronic renal failure, COPD, diabetes, hypertension, and obesity. The Chronic Diseases variable represents the likelihood and distribution of chronic conditions for a given population and time.

Cerebrovascular Diseases: "group of conditions that affect blood flow and the blood vessels in the brain" [84]. The model includes the following conditions: diabetes, hypertension, obesity, and smoking. The Cerebrovascular Diseases variable represents the likelihood and distribution of cerebrovascular conditions for a given population and time.

Immunosuppression: "decreased capacity to neutralize external organisms, which may result in repeated, more severe, or prolonged infections, as well as an increased susceptibility to cancer development" [85]. This variable represents the likelihood and distribution of immunosuppression conditions for a given population and time.

Cancer: the likelihood and distribution of cancer disease for a given population and time [86].

Chronic Liver Diseases: "gradual destruction of liver tissue over time" such as cirrhosis and Fibrosis of the liver diseases [87]. This variable represents the likelihood and distribution of chronic liver diseases for a given population and time.

Congenital Heart Disease: the likelihood and distribution of congenital heart defects for a given population and time [86].

Genetic Disorders: "disease caused in whole or in part by a change in the DNA sequence away from the normal sequence" [88].This variable represents the likelihood and distribution of genetic disorders for a given population and time.

Inherited Metabolic Disorders: the likelihood and distribution of inherited metabolic disorders for a given population and time [86].

Smoking: the likelihood and distribution of current or former cigarette smokers for a given population and time [86].

Chronic Renal Failure: the likelihood and distribution of chronic renal failure diseases for a given population and time [86].

COPD: the likelihood and distribution of chronic obstructive pulmonary diseases (COPD) for a given population and time. It includes emphysema and chronic bronchitis. [86].

Asthma: the likelihood and distribution of asthmatic people for a given population and time [86].

Obesity: the likelihood and distribution of obese people for a given population and time [86].

Diabetes: the likelihood and distribution of diabetic people for a given population and time [86].

Hypertension: the likelihood and distribution of hypertension cases for a given population and time [86].

Hemoglobin Disorders: the likelihood and distribution of hemoglobin disorders for a given population and time. It includes sickle cell disease (SCD) and thalassemia. [86].

Neurological Conditions: the likelihood and distribution of neurological conditions such as dementia for a given population and time. [86].

Demographics

Gender: the likelihood and distribution of sex for a given population and time. [82].

Pregnant: the likelihood and distribution of pregnant people for a given population and time. [86].

Pregnant: the likelihood and distribution of pregnant people for a given population and time. [86].

Health of the Workforce (Supply Chain):

Ethnicity: the likelihood and distribution of workforce's race from a supply chain system for a given population and time. [82].

Gender: the likelihood and distribution of workforce's sex from a supply chain system for a given population and time. [82].

Age: the likelihood and distribution of workforce's age from a supply chain system for a given population and time. [82].

Proximity at Workplace: the likelihood and intensity of concentration of people for a given supply chain workplace and time. Mobility data from mobile devices and social media are useful to characterize this variable, and its effect on COVID-9 spread at the workplace [78].

Absenteeism: the likelihood and intensity of number of absent workers due to health related issues [89].

Health of the workforce (Healthcare):

Ethnicity: the likelihood and distribution of workforce's race from a healthcare system for a given population and time. [82].

Gender: the likelihood and distribution of workforce's sex from a healthcare system for a given population and time. [82].

Age: the likelihood and distribution of workforce's age from a healthcare system for a given population and time. [82].

Proximity at Workplace: the likelihood and intensity of concentration of people for a given healthcare workplace and time. Mobility data from mobile devices and social media are useful to characterize this variable, and its effect on COVID-9 spread at the workplace [78].

2.2.2 Health System Services

Critical support systems

Transportation: the availability of emergency medical transportation such as ambulances in a given location and time [70].

Demand for Health Services: the likelihood and intensity of demand for critical support systems to provide healthcare services [90].

Human resources

Doctors: the availability of medical doctors to provide healthcare services in a given location and time [90].

Nurses/Midwives: the availability of nurses and midwives to provide healthcare services in a given location and time [91].

Graduates of Health Training Institutions: the availability of graduates from health training institutions to provide healthcare services in a given location and time.

Non-medical Staff: the availability of non-medical staff such as pharmacists, social workers, general staff, etc. for a given location and time [90].

Volunteerism: the availability of medical volunteers to provide healthcare services for a given location and time [90]

Access (Waiting Time): the degree and likelihood of time to wait for accessing to healthcare services provided by medical staff in a healthcare facility or system in a given location and time [92].

Demand for Health Services: the likelihood and intensity of demand for human resources to provide healthcare services [90].

Equipment

Infusion Devices: the availability of infusion devices to provide healthcare services in a healthcare facility or system in a given location and time [90].

Mechanical Ventilators: the availability of mechanical ventilators to provide healthcare services in a healthcare facility or system in a given location and time [90].

Monitors: the availability of monitors to provide healthcare services in a healthcare facility or system in a given location and time [90].

Demand for Health Services: the likelihood and intensity of demand for medical equipment to provide healthcare services [90].

Pharmaceuticals

Antimicrobial Therapy: the availability of antimicrobial therapy to provide healthcare services in a healthcare facility or system in a given location and time [90].

Antiviral: the availability of antiviral to provide healthcare services in a healthcare facility or system in a given location and time [89].

Prophylactic Treatment: the availability of prophylactic treatment to provide healthcare services in a healthcare facility or system in a given location and time [90].

Demand for Health Services: the likelihood and intensity of demand for pharmaceuticals to provide healthcare services [90].

Supplies

Hemodynamic Support: the availability of hemodynamic support to provide healthcare services in a healthcare facility or system in a given location and time [90].

PPE: the availability of proper personal protective equipment (PPE) for healthcare workers in a healthcare facility or system in a given location and time [90].

Supplemental Oxygen: the availability of supplemental oxygen to provide healthcare services in a healthcare facility or system in a given location and time [90].

Demand for Health Services: the likelihood and intensity of demand for medical supplies to provide healthcare services [90].

Physical infrastructure/facilities

Public Hospitals: total number of public hospitals [4].

Private Hospitals: total number of private hospitals [4].

Emergency Departments: the availability of emergency department facilities to provide healthcare services in a healthcare system at a given location and time [70].

Public Intensity Care Unit (ICU) Beds: the availability of ICU beds to provide healthcare services in a public healthcare facility or system at a given location and time [70].

Private Intensity Care Unit (ICU) Beds: the availability of ICU beds to provide healthcare services in a private healthcare facility or system at a given location and time [70].

Intensity Care Unit (ICU) Beds: the availability of ICU beds to provide healthcare services in a healthcare facility or system at a given location and time [70].

Mental Healthcare Departments: the availability of mental healthcare department facilities to provide healthcare services in a healthcare system at a given location and time [70].

Neonatal Care: the availability of neonatal care facilities to provide healthcare services in a healthcare system at a given location and time [70].

Public Non-ICU Beds: the availability of non-ICU beds to provide healthcare services in a public healthcare facility or system at a given location and time [70].

Private Non-ICU Beds: the availability of non-ICU beds to provide healthcare services in a private healthcare facility or system at a given location and time [70].

Non-ICU Beds: the availability of non-ICU beds to provide healthcare services in a healthcare facility or system at a given location and time [70].

Operating Rooms: the availability of operating room facilities to provide healthcare services in a healthcare system at a given location and time [70].

Pharmacies: the availability of pharmacy facilities to provide pharmaceuticals and medical supplies in a healthcare system at a given location and time [70].

Access (Waiting Time): the degree and likelihood of time to wait for accessing to healthcare facilities in a healthcare system at a given location and time [92].

Demand for Health Services: the likelihood and intensity of demand for physical infrastructure and facilities to provide healthcare services [90].

Information System

Patient Tracking & Identification: the availability of a patient level tracking and identification system to record, track, and identify all patients [91].

2.2.3 Supply Chain

Vendor/Supplier

Geographical Location (V): place where a particular point or object exists. It is often given in terms of latitude and longitude [93]. In this case refers to the place where the facilities of the Vendor/Supplier are located.

Labor Shortage (Supplier): likelihood of a disequilibrium in the market between supply and demand, where the quantity of workers demanded exceeds the supply available and willing to work at a particular wage and working conditions at a particular place and time. It is measured as the difference between the demanded and the available workers for a given set of conditions. [94]. This variable measures the *labor shortage* in the Vendor/Supplier.

Value of Product (V): worth in monetary terms of the technical, economic, service, and social benefits a customer company receives in exchange for the price it pays for a product. Typically measured in monetary terms per unit [95].

Type of Product: set of characteristics of offered goods and/or services. Products can be classified according to offering, purchase frequency, and features [96]. This variable refers to the type of product offered by the Vendor/Supplier.

Raw material availability: availability of prime materials from which a product is made. It is expressed as the ratio of available units of materials with respect to the required units. [97]. Shortage of raw materials is driven by institutional or structural inefficiency or by a physical limitation or constraint, among others. Its consequences can be of technological, geographical or operational in nature [98].

Resource Extraction: refers to activities involved in the withdrawal of raw materials from the environment, for further processing to add value. Extraction practices my or may not be sustainable, given their impact on the natural environment [99, 100]

Vendor Infrastructure Damage: the likelihood of direct physical damage or loss of functionality of the physical systems or networks that provide circulation of people, goods, services and information in the supply chain. Measured as the degree of loss of functionality of the infrastructure [101]

Vendor Closure: the likelihood of closure of system or networks of facilities of entities in the supply chain, in this case for the Vendor/Supplier [102].

IT & Cyber Compliance (V): set of security and safety standards aimed to assess, prevent, and mitigate IT & Cyber Risks [103]. This variable refers to the application of said standards in the operation of the Vendor/Supplier.

Vendor Computer Information System: availability of the system comprised by hardware and software applications that supports the integration and coordination of Supply Chains for effective Supply Chain Management in activities such as inventory management, production control, and order tracking among others [104].

Scheduling Production (V): process of defining the independent demand items an organization must produce and when they are needed, providing a detailed arrangement of the time and quantities that have to be produced or provided for various products.[105]. This variables captures the existence and degree of implementation of the scheduling process for the Vendor/Supplier.

Demand Planning: the process of "identifying, aggregating, and prioritizing, all sources of demand for the integrated supply chain of a product or service at the appropriate level, horizon and interval" [106].

Inventory Carrying Cost (V): measure of the costs incurred to hold inventory as a result of the cost of opportunity cost, shrinkage costs, insurance and taxes, obsolescence, theft, use of storage facilities and other causes. [106, 107].

Inventory Carrying Cost Rate (V): ratio of inventory carrying cost and total cost of inventory, measured typically as a percentage [107].

Vendor Delay: the likelihood of a 4late or postponed shipping of goods from the Vendor/Supplier to the Manufacturer, measured in time units. [108]

Vendor Capacity: measured limit or ability of physical facilities, personnel and process of an entity in the Supply Chain to meet the customer's needs for goods or services. It includes the ability to produce, store, transport or transform materials or services [109], [106]

Reputation (V): set of perceptions of stakeholders or individuals about what an organization represents and the way the firm manages its assets [103].

Action Trigger (V) (Reputation): reputation trigger, or component, related with the company's actions, including quality of management, treatment of employees, working conditions, resource utilization, long term investment, corporate social responsibility, and

firm's culture [103].

Offering Trigger (V) (Reputation): reputation trigger, or component, related with the products and services offered, availability of products and services, branding, inventiveness, consumer experience, and image of brand users [103].

Manufacturer

Geographic Location (M): see *Geographic Location (V)* . In this case refers to the place where the facilities of the Manufacturer are located.

Demand (M): the known quantity that will be purchased for a specific product or service based on open production orders from the Manufacturer to the Vendor/Supplier [106], [109].

Supply Delay: likelihood of late or postponed delivery of goods/services from the Vendor/Supplier to the Manufacturer, measured in time units. [108]

Supplier Clustering: "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementaries" [110]

Supply Shortage: likelihood of a scenario where the quantity demanded by the Manufacturer is greater than the quantity supplied by the Vendor/Supplier, according to its capacity [108].

Lead Time: time interval between the placement of an order by the Manufacturer, and its delivery from the Vendor/Supplier [109], [107].

Labor Shortage (M): see *Labor Shortage (Supplier)*. This variable applies for a labor shortage on the Manufacturer.

Value of Product (M): see *Value of Product (V)*. This variables applies for the *Value of Product* of the Manufacturer.

Type of Product (M): see *Type of Product (V)*. This variable refers to the *Type of Product* offered by the Manufacturer.

Safety Stock (M): extra stock that is held as a contingency against future variability of supply and/or demand, such as demand rising or suppliers being unable to deliver goods

[111].

Manufacturing Disposal Practices: activities and actions oriented to waste management including collection, transport, treatment and disposal of waste; control, monitoring and regulation of production. It also includes the prevention of waste production through reuse and recycling [112].

Manufacturing Infrastructure Damage: see *Vendor Infrastructure Damage*. This variable applies for the physical damage on the infrastructure of the Manufacturer.

Manufacturing Plant Closure: see *Vendor Closure*. Applies for the Manufacturer.

IT & Cyber Compliance (M): see *IT & Cyber Compliance*. This variable refers to the application of the standards in the operation of the Manufacturer.

Manufacturer Computer Information System: see *Vendor Computer Information System*. Applies for the Computer Information System that supports the Manufacturer's Operations.

Scheduling Production (M): see *Scheduling Production (V)*. This variable captures the existence and degree of implementation of the scheduling process for the Manufacturer.

Demand Planning (M): see *Demand Planning* in previous section. This variable applies for the Manufacturer's *demand planning*.

Inventory Carrying Cost (M): see *Inventory Carrying Cost (V)*. This variable refers to the *Inventory Carrying Cost* of the Manufacturer.

Inventory Carrying Cost Rate (M): see *Inventory Carrying Cost Rate (V)*. This variable refers to the *Inventory Carrying Cost Rate* of the Manufacturer.

Reputation (M): see *Reputation (V)*. This variable refers to the *Reputation* of the Manufacturer.

Action Trigger (M) (Reputation): see *Action Trigger (V) (Reputation* . This variable refers to the *Action Trigger* reputation component of the Manufacturer.

Offering Trigger (M) (Reputation): see *Offering Trigger (V) (Reputation*. This variable refers to the *Offering Trigger* reputation component of the Manufacturer.

Manufacturing Delay: analogous to *Vendor Delay*. The likelihood of late or postponed shipping of finished goods from the Manufacturer to the Retailer, measured in time units [108].

Finished Goods Supply: inventory of items that have been through the manufacturing process, can be sold as a completed items or as repair parts, and are ready for distribution. [106, 111].

Retailer

Geographic Location (R): see *Geographic Location (V)* . In this case refers to the place where the facilities of the Retailer are located.

Labor Shortage (R): see *Labor Shortage (M)*. This variable applies for a *Labor Shortage* for the Retailer.

Demand (R): the known quantity that will be purchased for a specific product or service based on open production orders from the Retailer to the Manufacturer [106], [109].

Supply Delay: the likelihood of late or postponed delivery of goods/services from the Manufacturer to the Retailer, measured in time units. [108]

Centralized Production: the likelihood of concentration within a particular location and/or group of manufacturing activities and companies that supply finished goods to the Retailer [109].

Supply Discontinuity: analogous to *Supply Shortage*. The likelihood of a scenario where the quantity demanded by the Retailer is greater than the quantity supplied by the Manufacturer, according to its capacity [108].

Lead Time (R): time interval between the placement of an order by the Retailer, and its delivery from the Manufacturer [109], [107].

Type of Product (R): see *Type of Product (V)*. This variable refers to the type of product offered by the Retailer.

Value of Product (R): see *Value of Product (V)*. This variables applies for the Value of Products of the Retailer.

Safety Stock (R): see *Safety Stock (M)*. This variable applies for the Retailer's *Safety Stock*.

Retailer Infrastructure Damage: see *Vendor Infrastructure Damage*. This variable applies for the physical damage in the infrastructure of the Retailer.

Retailer Closure: see *Vendor Closure*. Applies for the Retailer's facilities.

Working Conditions: "refers to the working environment and aspects of an employee's terms and conditions of employment. This covers such matters as: the organisation of work and work activities; training, skills and employability; health, safety and well-being; and working time and work-life balance" [113].

IT & Cyber Compliance (R): see *IT & Cyber Compliance*. This variable refers to the application of the standards in the operation of the Retailer.

Retailer Computer Information System: see *Vendor Computer Information System*. Applies for the *Computer Information System* that supports the Retailer's Operations.

Demand Planning: see *Demand Planning (M)* in previous section. This variable applies for the Retailer's *Demand Planning*.

Inventory Carrying Cost: see *Inventory Carrying Cost (V)*. This variable refers to the *Inventory Carrying Cost* of the Retailer.

Inventory Carrying Cost Rate (R): see *Inventory Carrying Cost Rate (V)*. This variable refers to the *Inventory Carrying Cost Rate* of the Retailer.

Reputation: see *Reputation (V)*. This variable refers to the *Reputation* of the Retailer.

Action Trigger (R) (Reputation): see *Action Trigger (V) (Reputation)*. This variable refers to the *Action Trigger* reputation component of the Retailer.

Offering Trigger (R) (Reputation): see *Offering Trigger (V) (Reputation*. This variable refers to the *Offering Trigger* reputation component of the Retailer.

Retailer Delay: analogous to *Vendor Delay*. Late or postponed shipping of goods from the Retailer to the Customer, measured in time units. [108]

Retailer Inventory Level: stock of goods or products in a facility which are intended to be sold in a specific period [111], [106].

Customer

Geographic Location (C): see *Geographic Location (V)* . In this case refers to the place where the Customer, or the Customer's facilities are located.

Demand (C): the known quantity that will be purchased for a specific product or service based on open production orders from the Customer to the Retailer [106], [109].

Lead Time (C): time interval between the placement of an order by the Customer, and its delivery from the Retailer [109], [107].

Supply Delay: the likelihood of a late or postponed delivery of goods/services from the Retailer to the Customer, measured in time units. [108]

Supply Discontinuity: analogous to *Supply Shortage*. The likelihood of a scenario where the quantity demanded by the Customer is greater than the quantity supplied by the Retailer, according to its capacity [108].

Logistics Operator

Logistics Personnel Shortage: see *Labor Shortage (M)*. This variable applies for a labor shortage on the Logistics Operator.

Transportation Restrictions/Disruptions: the likelihood that set of constraints of varying nature, such as regulatory, economic, or environmental reduce the transportation capacity of the Logistics Operator. [114].

Transportation Mode: method of transportation used to move goods from one point to another [107], [106].

IT & Cyber Compliance: see *IT & Cyber Compliance*. This variable refers to the application of the standards in the operation of the Logistics Operator.

Logistics Computer Information System: see *Vendor Computer Information System*. Applies for the Computer Information System that supports the Logistics operations.

Tracking System: set of technologies used to monitor and record the location of shipments as they move throughout the supply chain [106]. This variable refers to the application of tracking technologies by the Logistics Operator.

Transportation Cost: total expenditures for the movement of freight from one point to another [105].

Routing and Scheduling: process of determining how shipments will move across the supply chain, including detailed information about carriers involved, routes, and estimated time enroute [106].

Material/Product Geographical Location: see *Geographical Location (V)* This variables refer to the place where the materials or products are located while being transported.

Transport Greenhouse Gases Emissions: emission of gases contributing to the greenhouse effect, such as carbon dioxide, nitrous oxide, methane, ozone, and chloro-fluorocarbons, resulting from transportation activities [112].

Mode Reliability: refers to the consistency of a transportation mode to meet customer requirements in terms of pickup and delivery times of goods or materials [105].

Storage & Distribution Capacity: measured limit or ability of physical facilities, personnel and process of a Logistics Operator for an effective flow and storage of goods or services, meeting the customer's requirements [109], [106].

Mode Security: the likelihood for a shipment to be the target of piracy or theft, in relation with the transportation mode [105].

2.3 Impacts

2.3.1 Environmental

Climate-related metrics

Carbon Budget: the magnitude and likelihood of greenhouse gas emissions from a supply chain system at a given location and time [115].

Sustainable Development Goals

Sustainable Development: the degree and likelihood of achieving sustainable goals including water security and waste control in a given location and time [116].

2.3.2 Economic

Supply Chain performance metrics

Wage Increase: likelihood of wage increase as a consequence of labor shortage in the entities of the Supply Chain [117].

SC Labor Cost: expenses originated from salaries attributed to the usage of direct labor in the entities of the Supply Chain [107].

Inventory Carrying Cost: see *Inventory Carrying Cost (V)*. This variable refers to the total *Inventory Carrying Cost* in the Supply Chain.

SC Transportation Cost: see *Transportation Cost*. This variable refers to the total *Transportation Cost* in the Supply Chain.

On-time delivery: the likelihood that a scheduled shipment is delivered on the expected date, or within an allowable tolerance [107].

Invoice reduction per order: deduction in an invoice, requested by a customer, to get a compensation for inconveniences or added costs after a service failure [105].

Lost sales/returned ratio: ratio of the customers experiencing service failure that request the orders to be corrected to the customers that refuse the orders [105].

Order Value: total revenue by orders delivered in full [105].

Rehandling Cost: costs associated with correcting orders, such as reshipping correct items and returning incorrect and refused items, after a service failure [105].

Service Failure: likelihood of an entity of the supply chain of failing to fulfill customer's orders in a satisfactorily manner [105].

Customer Satisfaction: measure of satisfaction of customers with the quality of the goods and services offered, and delivered [106].

% or Orders delivered in full: percentage of orders that are received by the customer in the quantities committed with respect to the total number of orders [107].

2.4 States of Risk

2.4.1 Social

Death-related indexes

Deaths (Community): total number of deaths at the community level conditioned by *Community Health*.

Deaths (Deaths (Supply Chain): total number of deaths in the Supply Chain Workforce conditioned by the *Health of the Workforce (Supply Chain)* variable.

Deaths (Healthcare): total number of deaths in the Healthcare Workforce conditioned by the *Health of the Workforce (Healthcare)* variable.

Mortality/Fatality: ratio of total number of deaths to total population in a time interval. It is a measure of the frequency of occurrence of death in a defined population [118]

Infant Mortality: ratio of number of deaths among children under 1 year of age to the total number of births reported during a specified time interval [118].

Health indexes

Recovered Cases: total number of SARS-CoV-19 recovered cases at the community level.

Life Expectancy: refers to the average number of years a person may expect to live [119].

Hospitalizations: estimated number of people hospitalised [4].

Social Status

Estimated Education Level: estimated distribution of the highest levels of education achieved in a community. The International Standard Classification of Education (ISCED) suggest 8 levels of education based on the complexity of educational content [62].

2.4.2 Environmental

Climate-related metrics

Climate Change Abatement: the degree of reduction of greenhouse gas emissions from supply chain systems at a given location and time [115].

Climate Regulation: the degree of ecosystem services to store greenhouse gas emissions due to supply chain systems activities [120].

Sustainable Development Goals

Water and Food Provisioning: the degree of securing provision of food and water to a population at a given location and time [121].

Natural Heritage: the degree of conservation of habitats of threatened animal and plant species, and sites with natural value such as research significance or natural beauty [122].

2.4.3 Economic

Supply Chain Performance Metrics

Operational Cost: daily expenses originated by the execution of a company's activities, including salaries, transportation and warehousing, and inventory carrying costs. [105], [111].

Cash-to-cash Cycle Time: average elapsed time between payment to a vendor for materials or services and the receipt of payment from a customer for shipments [107].

Service Failure Cost: cost associated with the inability of an entity of the supply chain to correctly fulfill customer's orders. These costs originate from lost sales of refused orders, invoice deduction of rectified orders, and rehandling costs associated with correcting the orders. [105].

Total Supply Chain Management Cost: in the context of the model, this variable represents the total implementation cost of active and passive countermeasures that mitigate the vulnerability of the entities in the Supply Chain System. In Supply Chain Management literature, *Total Supply Chain Management Cost* refers to the total costs to "manage order processing, acquire materials,manage inventory, and manage supply-chain finance, planning, and IT costs, as represented as a percent of revenue" [106].

Business metrics

Unemployment: refers to the percentage of workers in the labor force who do not have currently a job [123].

Revenue: amount of income originated from sales made to customers that comes into a business [111, 106].

Reputation: see *Reputation (V)*. This variable represents the economic state of Risk derived from the Reputation of the entities in the Supply Chain.

2.4.4 Socioeconomic

Socioeconomic Status

State of Income: estimated mean income computed for every person in a census tract [2].

Unemployment: estimated civilian persons unemployed divided by total civilian population. [2].

Poverty: estimated set of money income thresholds that vary by country, family size, and composition to determine the degree of poverty [56, 57].

3 Variable Definitions for Risk Assessment & Management Model

3.1 Active Countermeasures

Laws & Regulations

Law Enforcement: enforcement mechanisms to ensure an effective and efficient application of laws and regulations [54].

Laws and Regulations: set of policies and regulations to mitigate the effect of threats on vulnerable systems, or to reduce a state of vulnerability of a system [54].

School Regulations: set of policies and regulations aimed at mitigating the spread of SARS-CoV-19 in educational institutions, including reduction of activities or school closures [124].

Travel Regulations: set of policies applied to human travel within national borders and across countries, aimed at mitigating the spread of COVID-19 [117].

Social Distancing Regulations: this variable refers to the characteristics and validity of policies and regulations pertinent to the physical distancing in a society with the objective to mitigate the spread of COVID-19.

Transportation Regulations: set of policies and restrictions that apply to different modes of transportation in order to mitigate the spread of COVID-19 [125].

COVID-19 Active Countermeasures

Personal sanitation and cleaning: cleaning and sanitation practices including washing your hands and using hand sanitizer [126].

Surface cleaning and disinfection: the use of bleach and isopropyl alcohol (IPA) to clean and sanitize contaminated surfaces by SARS-CoV-2 [127].

Improve/implement ventilation system: ventilation and filtration provided by heating, ventilating, and air-conditioning (HVAC) to reduce COVID-19 Airborne transmission [126].

Testing: COVID-19 testing mechanisms applied to a population in a given location and time. This variable is strongly conditioned on the availability of tests, and proper facilities for testing [128].

Quarantine: quarantine mechanisms such as self-isolation and mandatory state-managed quarantine [129].

Contact Tracing: set of methods to identify people who have been in close contact with a COVID-19 positive case [129].

Food & Water Treatment

Education to encourage the proper cooking of food: education mechanisms to inform about how to proper cook certain meats that could contain diseases [47].

Water treatment: water treatment mechanisms to ensure safe drinking water for a population [47].

3.2 Passive Countermeasures

COVID-19 Passive Countermeasures

Essential services regulations: regulations that define the set of industries and business activities that are typically instrumental to continue critical infrastructure viability, and in which their workers are allowed to access their workplaces during times of community restrictions [130].

Workplace regulations: regulations pertaining to social distancing, employee shifts, employee in-person interaction with public, feasibility of teleworking, workplace geographic isolation, policies regarding sick leaves, priority for operations continuity, among others to create a safe workplace for workers and clients, reducing the overall exposure to SARS-CoV-2 [131].

Vaccination: vaccines applied to a population in a given location and time. This variable is strongly conditioned on the availability of vaccines, and proper facilities for vaccination [89].

Healthcare Services Management

Credentialing and regulations: credentialing and verification processes to ensure that volunteers that intend help on providing healthcare services are trained and certified [91].

Inventory Management (Healthcare): process of ensuring availability of products through safe and efficient control, storage, and replenishment of stock [111, 107]. This variables refer

to the management of products and materials required in Healthcare Services.

Financial contingency plan: contingency resources to acquire equipment, human resources (including payroll), pharmaceuticals, and supplies that are not used on a day-to-day basis [132].

Alternate care sites: availability of designated areas to provide immediate care such as waiting rooms, hallways, cafeterias, offices, schools, large restaurants, hotels, etc. [132].

Emergency preparedness and response training: initial and periodic disaster training exercises, e.g. "principles of healthcare delivery using PPE" [133].

Cybersecurity management: set of security and safety standards aimed to assess, prevent, and mitigate IT & Cyber Risks [103]. This variable refers to the application of said standards in the operation of the entities of the Supply Chain and Healthcare Services systems.

Supply Chain Management

Multi-modal transportation: practice of using more than one transportation mode, such as motor, water, and air carriers during the movement of materials or goods [109, 106].

Cybersecurity management: see *Cybersecurity management* in the previous section. This is the same variable. It is included in this section, because it is also a parent node for variables on the Supply Chain System [134].

Supply Diversification: act of increasing the flexibility and choices of sources of supply for certain products, materials, and/or services, mitigating potential impacts on material availability of political or geographical causes [135].

Inventory management: see *Inventory Management (Healthcare)*. This variable refers to Inventory Management in the Supply Chain entities.

Recycling & Disposal Management

Treatment facilities: specialized facility whose function is to change the physical, chemical, or biological characteristics of hazardous waste in order to neutralize such waste, recover energy material resources, render the waste nonhazardous o less hazardous, or render the waste safer to transport, store or dispose [136]. This variable refers to the use of *Treatment facilities* by the entities of the Supply Chain when dealing with waste.

Collection centers: specialized facility in charge of holding hazardous materials temporarily, before being treated, disposed of, or stored somewhere else [136]. This variable refers to the use of *Collection Centers* by the entities of the Supply Chain when dealing with waste.

Recycling and disposal: recycling refers to the processing and use of waste within production and consumption processes [112]. Disposal is the discharge, deposit, dumping, spilling, or placing of solid or hazardous waste in a facility at which the waste will remain after closure [136]. This variable refers to the application of *Recycling*, and *Disposal* practices by the entities in the Supply Chain.

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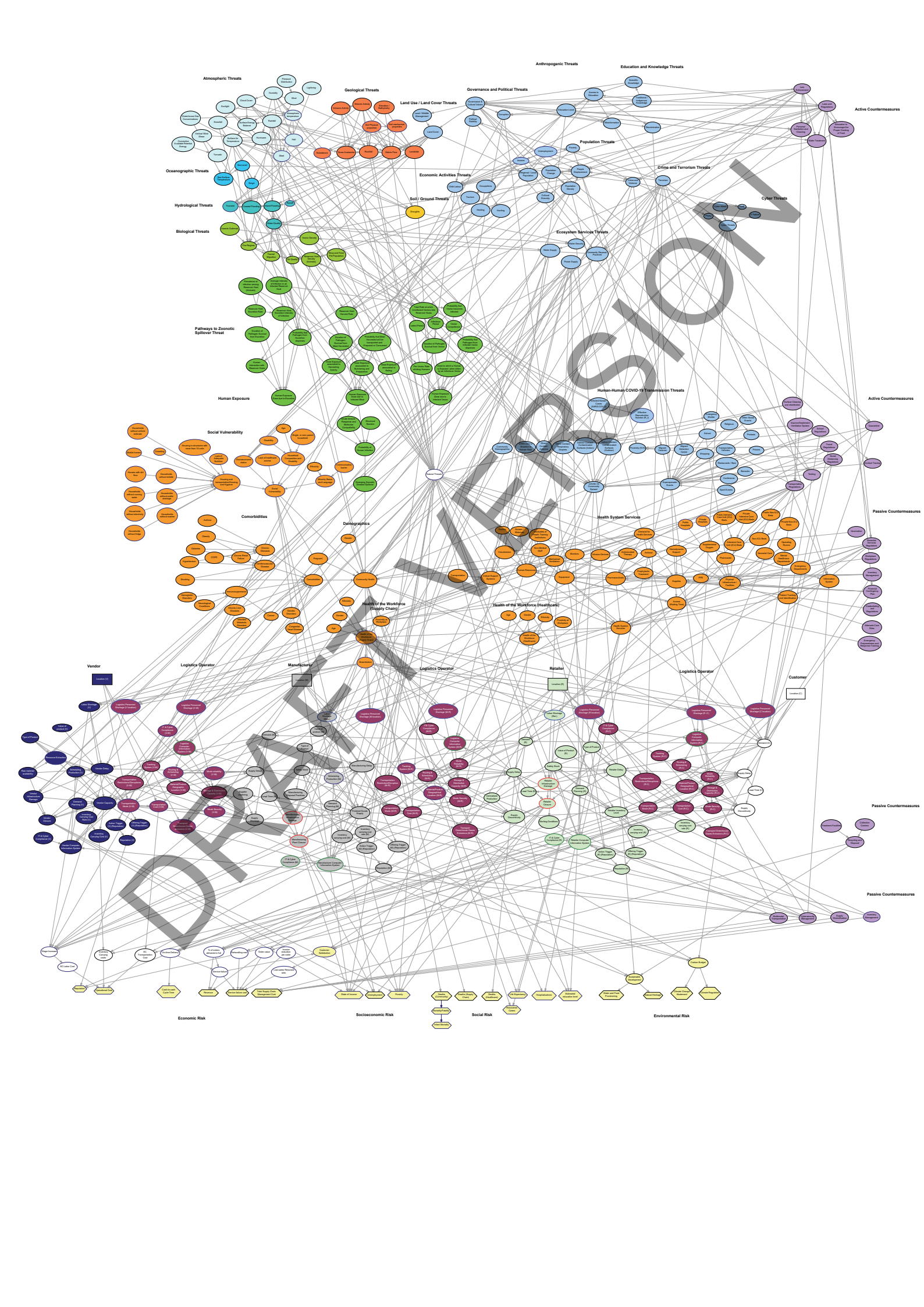
A Bayesian Network models

A.1 Risk Assessment & Management models

- Complete model, one location

Risk Assessment & Management
Complete Model
One location


Atmospheric Threats
Geological Threats
Land Use / Land Cover Threats
Governance and Political Threats
Anthropogenic Threats
Education and Knowledge Threats
Active Countermeasures
Oceanographic Threats
Economic Activities Threats
Population Threats
Crime and Terrorism Threats
Hydrological Threats
Soil / Ground Threats
Cyber Threats
Biological Threats
Ecosystem Services Threats
Pathways to Zoonotic Spillover Threat
Human Exposure
Human-Human COVID-19 Transmission Threats
Active Countermeasures
Social Vulnerability
Comorbidities
Demographics
Health System Services
Passive Countermeasures
Health of the Workforce (Supply Chains)
Health of the Workforce (Healthcare)
Vendor
Logistics Operator
Manufacturer
Logistics Operator
Retailer
Logistics Operator
Customer
Passive Countermeasures
Passive Countermeasures
Economic Risk
Socioeconomic Risk
Social Risk
Environmental Risk