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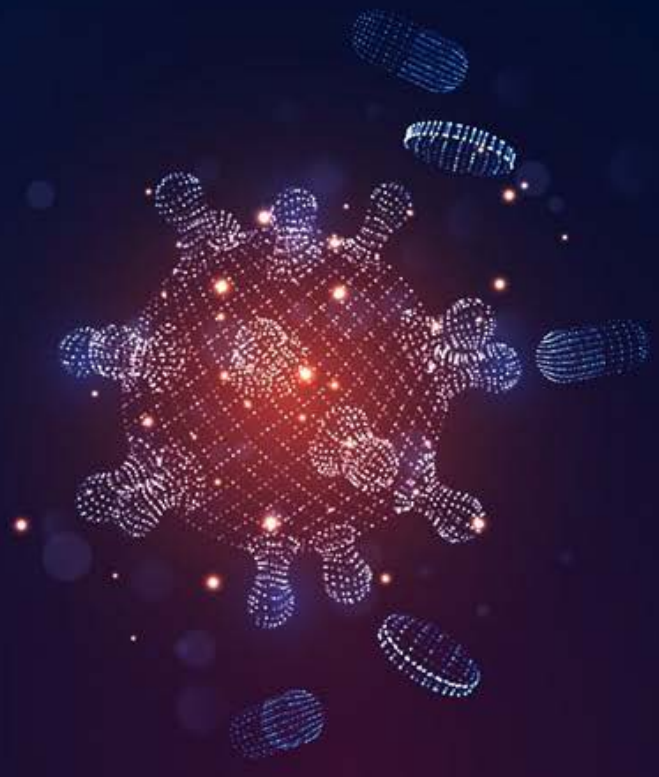
Business for South Africa

COVID-19 Response

Dynamic Risk Assessment Findings

April 2020



Executive summary

Fifteen major strategic risks were identified by Business for South Africa (B4SA) in the fight against COVID-19. These risks were assessed by B4SA survey participants for severity and likelihood but it soon became apparent that there was considerable interconnection between them and they formed a network of risks. As such, mitigation cannot be approached on a piece-meal basis: it needs to be addressed as an interactive, dynamic environment in which each component's effect on the others is taken into account. This report addresses this.

The most severe and likely individual, or discrete risks are:

- *Economic impact / damage. Lockdown economically unaffordable*
- *Insufficient healthcare, workforce, infrastructure and equipment*
- *Loss of livelihoods, social unrest, riots*
- *Sustainability and practicality of lockdown rules in SA context*

The risk combinations (risk clusters) most expected to be encountered, whose impact would be felt within one month if they occurred, are permutations of:

- *Sustainability and practicality of lockdown rules in SA context*
- *Loss of livelihoods, social unrest, riots*
- *Economic impact / damage. Lockdown is economically unaffordable*
- *Inability to maintain law and order*
- *Breakdown in the social compact between Government, business, labour and society*
- *Failure in critical infrastructure – energy, water, sanitation, gas, IT*
- *Supply chain security for essential services and goods*

The risk with the greatest impact or flow-on effect onto every other risk, and therefore the single risk with the discrete potential of avoiding the combinations above, is *Inability to maintain law and order.* Mitigate it, and it reduces the likelihood / severity of every other risk - directly or indirectly.

Economic impact / damage. Lockdown economically unaffordable is the next most influential risk, followed by *Loss of livelihood, social unrest, riots* and *Continued Government service delivery respectively.* The level of influence drops after the latter risk.

If the risk system as a whole is not mitigated, it will end in *Loss of livelihoods, social unrest, riots*. This is the number one concern for business, attracting a higher concern than the economy itself. Being systemically the most vulnerable, its optimal mitigation comes from the most influential risk: *Inability to enforce law and order.* Mitigating this risk serves a three-fold purpose:

- It optimally protects the economy which, in turn, will spread throughout the network to mitigate every other risk in the most efficient manner
- It will maximally safeguard the economy from pivoting to a negative, destructive downward spiral dragging every other risk with it into a calamitous, collective outcome
- It offers the best possible protection against people not being able to generate income, losing their livelihoods, with unemployment mostly youth soaring, triggering a high risk of social unrest / riots that may become political. Widespread hunger, domestic violence, mental health, impact on education, civil disobedience and business / property risk

The next 'domino to fall' after *Loss of livelihoods, social unrest, riots* is expected to be *Economic impact / damage. Lockdown economically unaffordable.* This would lead to a *Breakdown in social compact between Government, business, labour and society* and, ultimately, an *Inability to enforce law and order.*

If these risks are allowed to occur at the same time, they will trigger an existential, calamitous risk to the country. As a result they cannot and should not be allowed to spread to each other. It is of the utmost importance.

It is helpful to consider the risk of *Economic impact / damage. Lockdown economically unaffordable.* This risk features as number two in terms of influence onto every other risk. But it is also the second ranked risk in terms of being affected by every other risk in the network. As such, it is an unstoppable force of momentum. It will either propel every other risk to an overall positive outcome, or it can pivot in an instant to impel every other risk into a downward spiral to end up with the most vulnerable risk: *Loss of livelihoods, social unrest, riots.* It offers no middle ground.

Executive summary

Further risks that are more influential in mitigating other risks than what they are themselves affected by those risks include:

- *Continued Government service delivery*
- *Failure in critical infrastructure - energy, water, sanitation, gas, IT*
- *Lack of structured interface - Government, business, labour and civilians*

These risks are systemically mitigation accretive: they mitigate on the overall risks more than on what is spent on their own mitigation, to reduce the overall risks beyond their individual mitigation. As such, they present powerful levers to Government to combat the current situation with maximum effect.

A risk that was identified as a left field disruptor that can trigger a system-wide outbreak is *Fair, transparent and equitable distribution of social funding*. Specific attention should be paid to it: any impression, whether created by social media, rumour, innuendo or otherwise (even fake news) can prompt it to trigger risks within the clusters identified earlier.

Lastly, risks that are not expected to be connected and that can be discretely delegated are:

- *Defining 'new normal'/vision /structural shifts required*
- *Another significant event occurring*
- *Regional / cross provincial lockdown impact exert additional strain*

Detailed content

1. Background, scope and approach

Why Dynamic Risk Assessment (DRA) ?

Motivation

The science of risk management has learnt, on 18 globally significant occasions post 1970, that risks affect each other and seldom occur neatly in isolation. Instead, they conjoin, frequently producing consequences far worse than any single risk portended. Examples include aeroplane disasters, nuclear meltdowns, oil rig catastrophes and pandemics.

As a result the diligent management of risks needs to include attention being paid to their interaction on each other, as a collective, complex adaptive system.

Extensive research into the matter found the methodology currently best suited to do this being networks. DRA combines the best that a number of sciences have to offer to produce a cognitive risk network that best represents experts' thinking - the wisdom of crowds – which has been found to be more accurate than a single expert can produce.

Strategic risk register

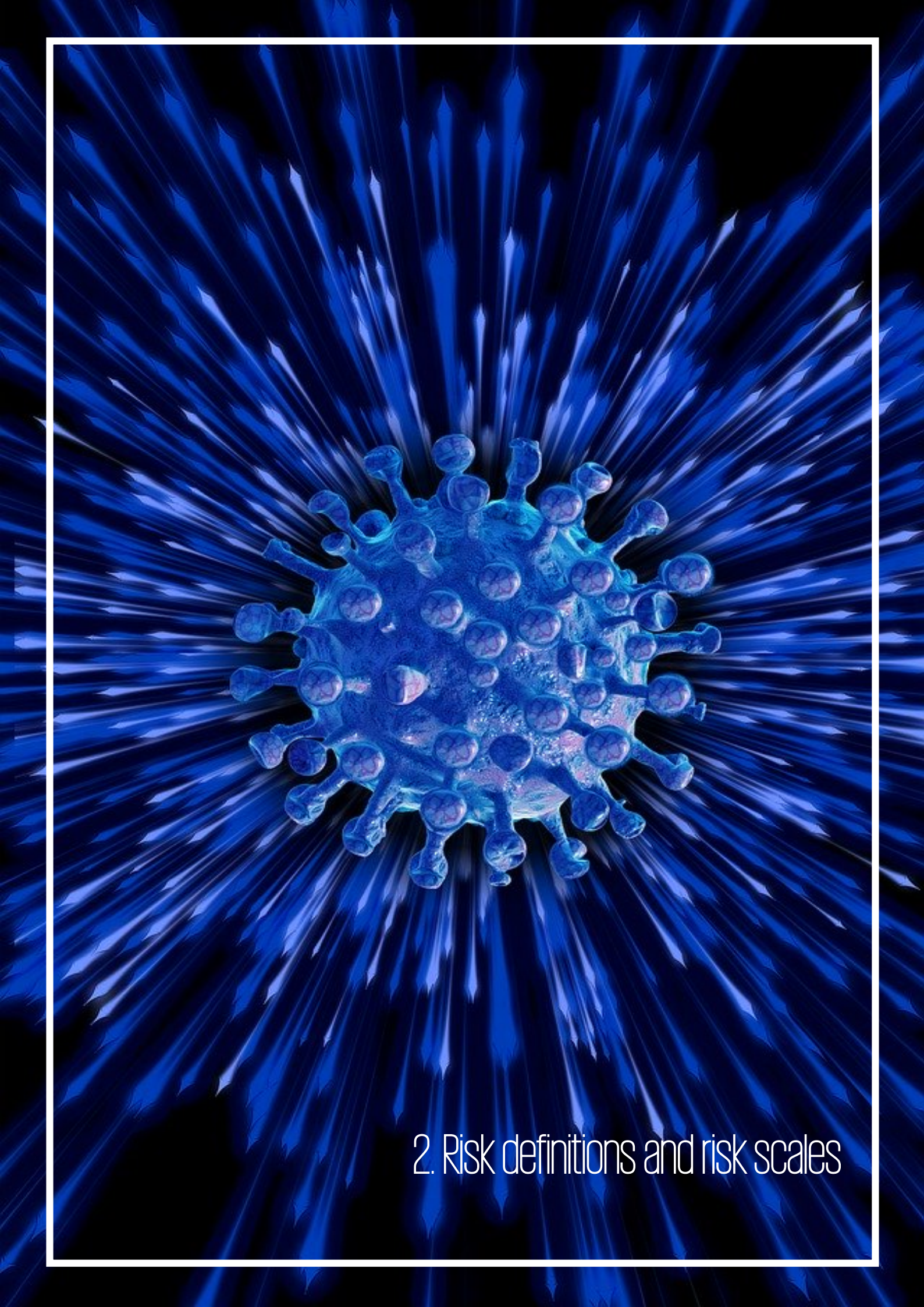
The 15 strategic risks in this report and used for the DRA process were based on the risk registers collated by B4SA and selected, individual interviews with key participants. The risks' severity and likelihoods were assessed by participants with reference to predefined logarithmic and probabilistic scales. The risks' interconnectedness were obtained from bias-controlled, Systems II inducing expert elicitation techniques.

Survey and results

Twenty five participants provided input data on 10 and 11 April 2020, making the results and findings robust and representative. These were presented to B4SA and the COVID-19 Steerco prior to the finalisation of this report.

Limitations

The approach adopted in this report draws on one application of graph theory. Other methods / alternative approaches may result in different results. A range of analyses and information should be considered before making decisions.



2. Risk definitions and risk scales

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The 15 strategic risks in this report and used for the DRA process were based on the Risk Registers collated by B4SA and selected, individual interviews with key participants. The risks' severity and likelihoods were assessed by participants with reference to pre-defined logarithmic and probabilistic scales. The risks' interconnectedness were obtained from bias-controlled, Systems II inducing expert elicitation techniques.

Table 1: Risk definitions

No.	Item	Description
1	**Another significant event occurring**	Possibility of another significant event at the time of lock-down / responding to COVID-19 / rebuilding economy. Reduced capacity to deal with it
2	**Breakdown in social compact between Government, business, labour and society**	Containment in densely populated / informal areas not possible. Citizens no longer heed Government for 'greater good', ineffectual communication, residential area spill over, trust dissipates, 'curve flattening' not understood
3	**Continued Government service delivery**	Government spheres' liquidity strains interrupting supply of critical infrastructure, services such as water, sanitation, electricity. Exacerbated by electioneering, strike action, multiple events occurring simultaneously
4	**Defining 'new normal' / vision / structural shifts required**	Need to determine what long-term industries / economic structural change / reform should look like. Balance between safety, security, law and order, basic needs (food and water), profit and people. Lack of unified rebuild focus (gov., business, society, trading partners). Seizing the moment vs complacency
5	**Economic impact / damage. Lockdown economically unaffordable**	Economy fragile and structurally flawed. Stimulus constraints More downgrades Sustainability of fiscal support. Reduced economic activity, confidence. Businesses highly geared Business failures. Unemployment. Structural reforms and rebuild too slow, difficult. Reduced trade and international protectionism
6	**Failure in critical infrastructure - energy, water, sanitation, gas, IT**	Lack of critical resources. Cyber-attacks. Knock-on effects of lockdown measures. Eskom loadshed. Lack of liquid fuels, gas and power. Collapse of communication infrastructure, SOE pressures
7	**Fair, transparent and equitable distribution of social funding**	Challenges with timing, qualification criteria, manner of distribution, identification and vetting of recipients, communication, bureaucracy
8	**Inability to enforce law and order**	Limitations in SAPS and SANDF. Inability to enforce interventions, law and order. Organised crime and corruption, increased criminality, domestic and public violence, premises and property damage, strained police and judicial system, inappropriate law enforcement. Political propaganda linked to service failures
9	**Insufficient healthcare, workforce, infrastructure and equipment**	Severely constrained resources. Impact of lock down on medical supplies. Contact tracing delays. Lack of critical supplies, facilities (beds, ICUs, ventilators, masks, test kits). Concentration of population with suppressed immunity. Inability to scale
10	**Lack of structured interface - Government, business, labour and civilians**	Disjointed, poor collaboration and communication between Government (including National Command Council), business, SMMEs, labour and civil society. Not applying lessons learned and benchmarking of other countries
11	**Leadership / command incapacitated by COVID-19**	Leadership / command team members incapacitated. Delayed decisions and responses, public panic / hysteria. Overseas reaction

Table 1: **Risk definitions (cont.)**

No.	Item	Description
12	**Loss of livelihoods, social unrest, riots**	Inability to flatten curve extends lockdown. Cannot generate income / loss of livelihoods. Unemployment soars, mostly youth, high risk of social unrest / riots – may become political. Hunger, domestic violence, mental health, impact on education, civil disobedience. Business / property risk
13	**Regional / cross provincial lockdown impact exert additional strain**	Inadequate healthcare / infrastructure in neighboring countries. Porous Boundaries. Provincial migration to access services. Unsynchronised lockdowns in neighboring countries. Economic and health migrants, increased crime and xenophobia, increase in rural to urban migration
14	**Supply chain security for essential services and goods**	South Africa's import reliance, import restrictions. Inability to move essential goods. Logistic / interpretation problems at ports, depots. Backlogs, regulatory hurdles and poor communication to public, interconnectivity and slowdown of entire supply chain, shortages - food
15	**Sustainability and practicality of lockdown rules in SA context**	Non-adherence / non-compliance to lockdown rules, impossibility thereof in townships, rural and informal settlements, inadequate housing and shelter, lack of water and sanitation, transport challenges, inadequate emergency supplies, fake news, lack of information on virus

The risk scales below were used by DRA survey participants to assess the severity, likelihood and velocity of the risks.

Table 2: **Severity - potential loss / impact rating**

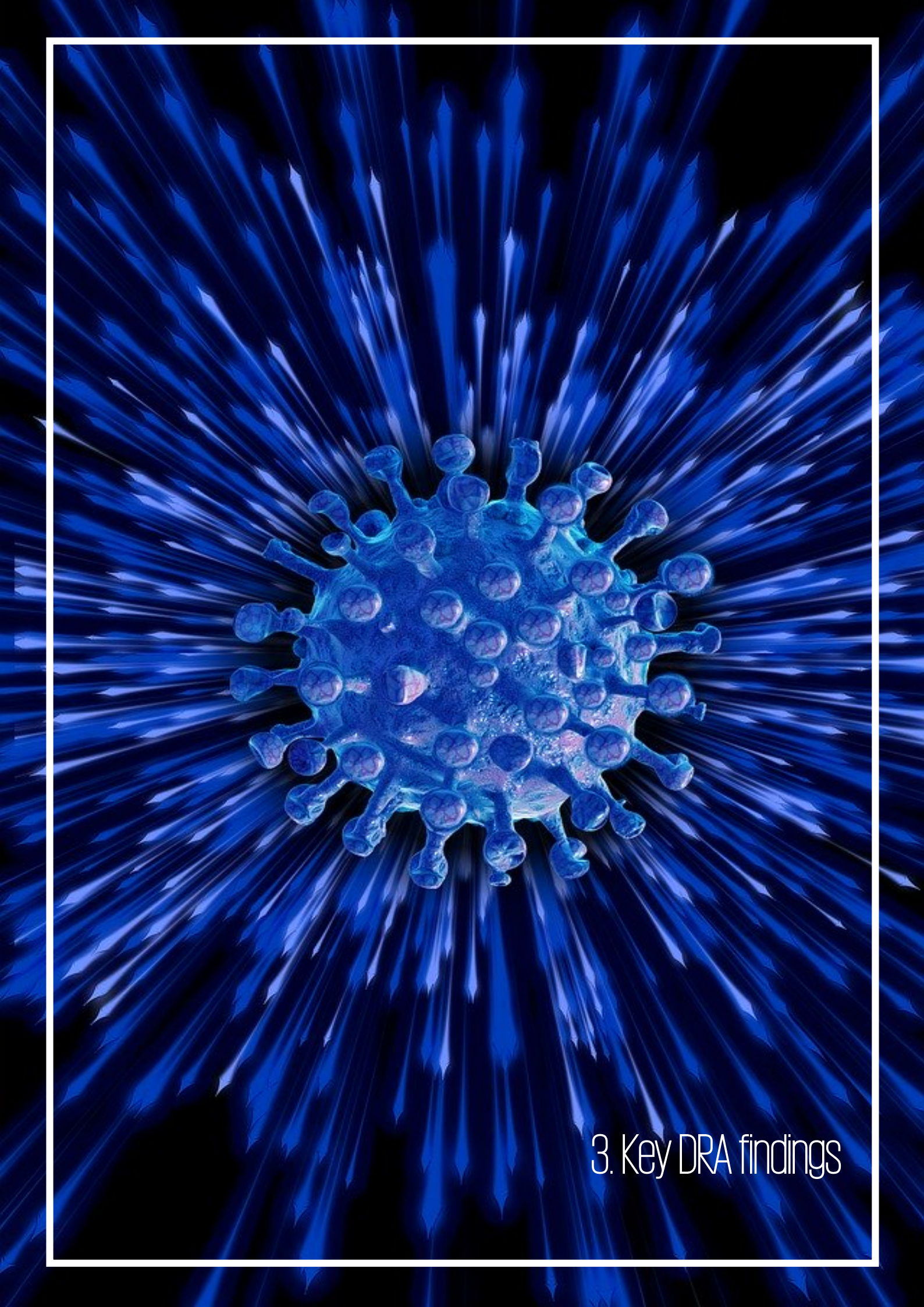
Impact factor	Score	General	Media and response	Stakeholders	Resources	Humanitarian
Catastrophic	100	Disaster leading to the collapse of the economy, infrastructure and services	Major negative media coverage with prolonged international, regional and national condemnation Fundamental disengagement of the majority of international and national stakeholders	Breakdown of the social compact between Government, Business, Labour and Civil Society Complete loss of trust and confidence in the Government	Complete disruption of critical infrastructure, supply chain, service delivery and collapse of business operations	Extensive and widespread loss of life and impact on livelihoods resulting in widespread unemployment, hunger, deprivation and impoverishment Breakdown in law and order, rampant civil and social unrest, unprecedented crime and violence
Critical	30	Critical events which can be endured but which may have a prolonged negative impact and extensive consequences	Extensive negative media coverage with some international criticism, regional and national public concern Significant disengagement of international and national stakeholders	Damage to the social compact between Government, Business, Labour and Civil Society Substantial loss of trust and confidence in the Government	Severe interruption of critical infrastructure, supply chain, service delivery and business operations	Severe and widespread loss of lives and material impact on livelihoods, significant unemployment, disruption of law and order Significant increased civil and social unrest, crime and violence
Serious	10	Major events, which can be managed but require additional resources and effort	Negative media coverage with some national criticism and limited regional public concern Disengagement of some important stakeholders	Strain on the social compact between Government, Business, Labour and Civil Society Reduced trust and confidence in Government	Reduction of critical infrastructure, supply chain, service delivery and business operations	Significant loss of life that may be widespread or dispersed. Impact on livelihoods, increased unemployment and social discontent
Significant	3	Event which can be managed under normal conditions	Limited negative media coverage with national public concern Damage to relationship with some stakeholders	Limited impact on the social compact between Government, Business, Labour and Civil Society Limited impact on trust in Government	Some interruption in business operations, supply chain constraints and strain on critical infrastructure	Some loss of life Difficult but endurable impact on livelihoods
Minor	1	Events that should be monitored but no immediate action is required	Limited adverse media coverage Limited relationship damage	No impact on the social compact between Government, Business, Labour and Civil Society	Minimal disruption of operations	Limited loss of life No serious impact on livelihoods

Table 3: Likelihood / probability of occurrence

Likelihood factor	Description	Probability of single occurrence within 12 months
Almost certain	The risk is almost certain to occur under the current circumstances	100.0%
Likely	More than an even chance of risk occurring	50.0%
Possible	A possible chance that the risk will occur	25.0%
Unlikely	Unlikely to occur	12.5%
Rare	A risk that will only occur in very rare circumstances	6.3%

Table 4: Velocity rating table

Time horizons (months)						
0.25	0.75	1.5	3	6	12	24



3. Key DRA findings

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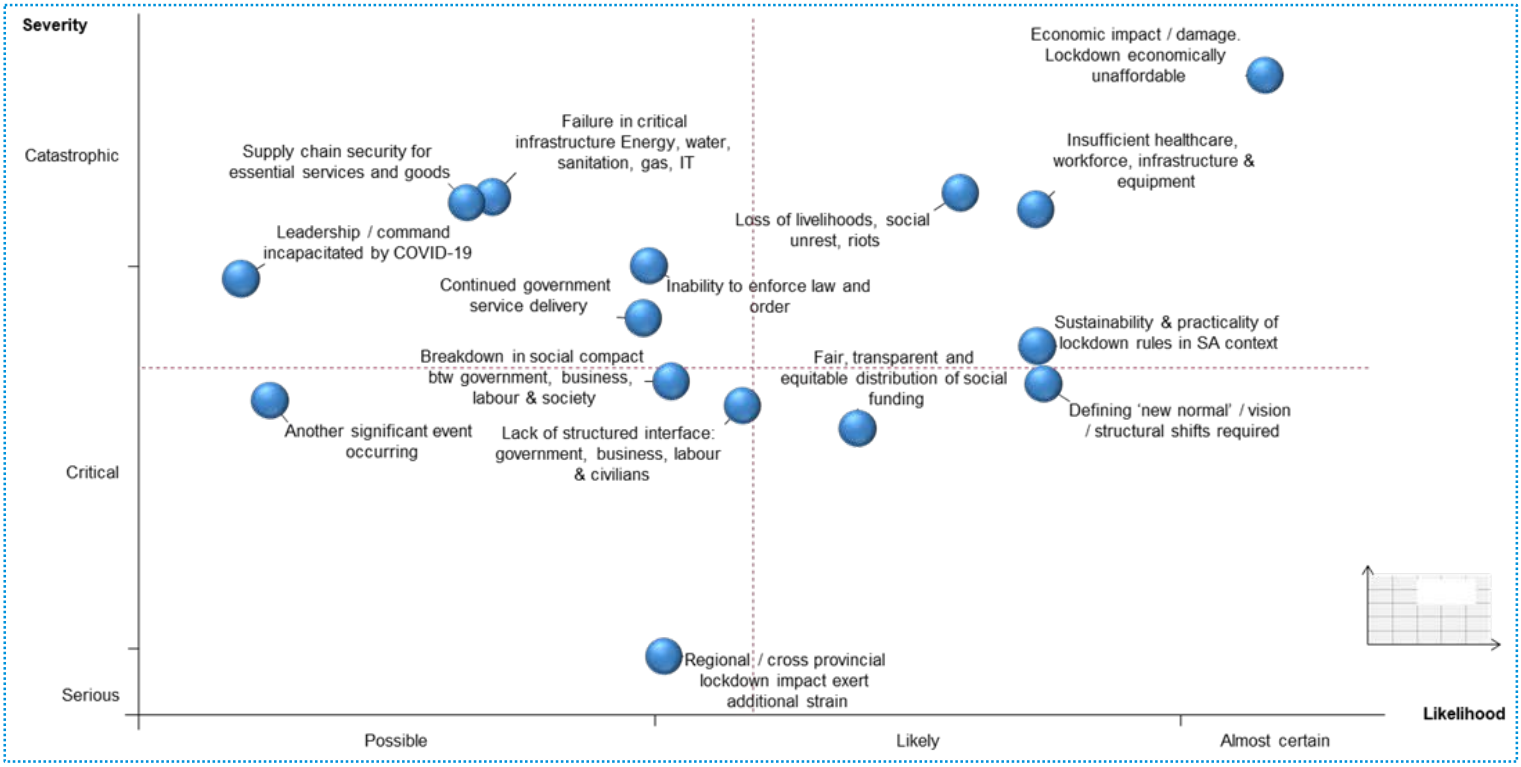
The South African Government is responding to the COVID-19 pandemic. Critical sectors across Government, health, labour, business and civil society have come together to address the challenges. Business for South Africa ('B4SA') initiated a Dynamic Risk Assessment (DRA) to assist in understanding the interconnected risk landscape.

Key risks foreseen by B4SA that impact South Africa were identified through the application of four criteria: severity, likelihood, velocity and interconnectedness. Based on these criteria, the salient findings below capture the risks which were identified as important:

Figure 1: Likelihood and severity of individual or discrete risks

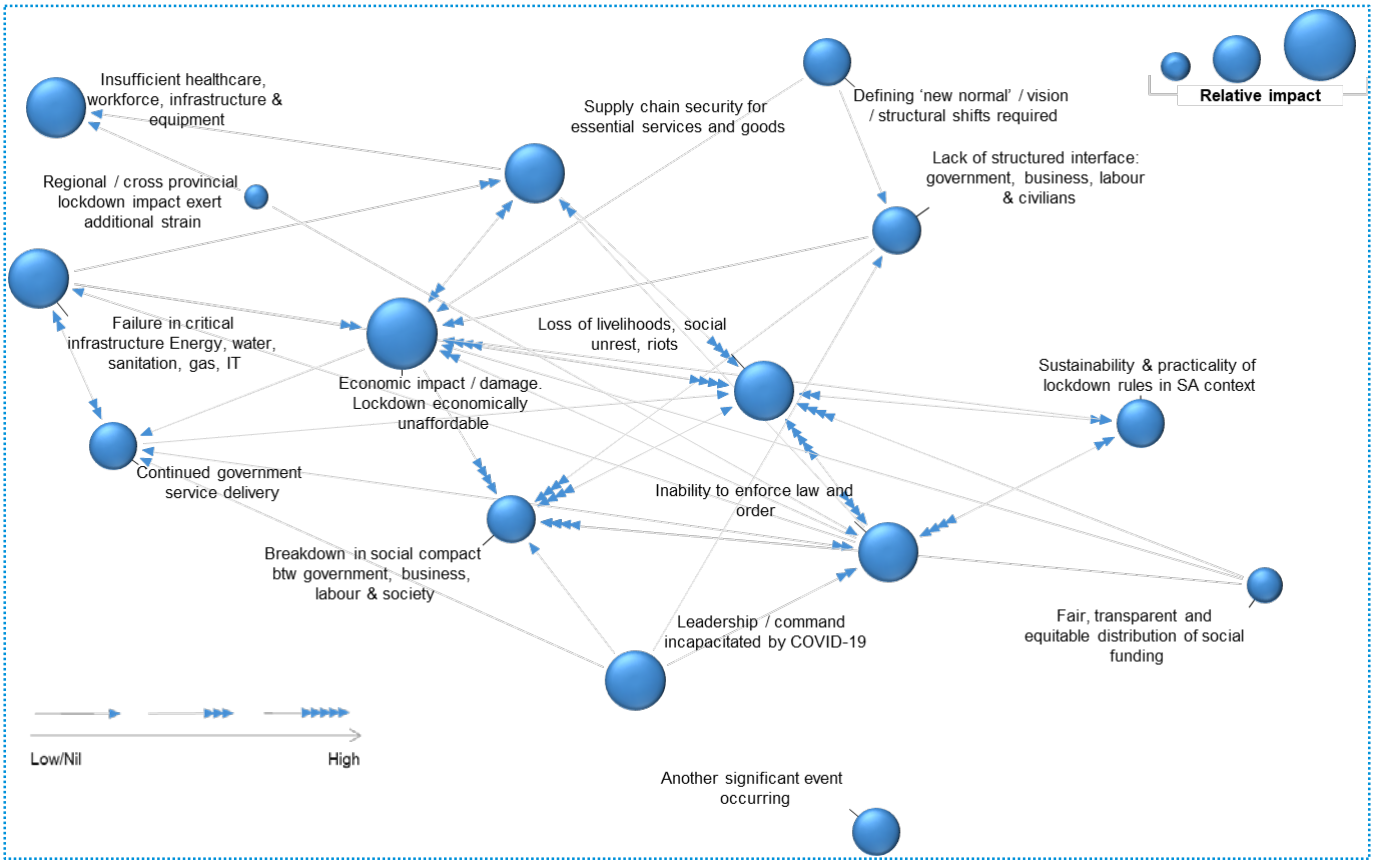


The most severe and likely individual, or discrete risks are ***Economic impact / damage. Lockdown economically unaffordable; Insufficient healthcare, workforce, infrastructure and equipment; Loss of livelihoods, social unrest, riots*** and ***Sustainability and practicality of lockdown rules in SA context.***

Importantly, these risks do not constitute separate, discrete threats; on the contrary they interact to affect and influence each other, so that focusing on one individually may trigger unintended consequences elsewhere in the risk environment. It is therefore important to determine how the risks manifest as a dynamic system in order to identify the most optimal ways to mitigate the totality of the threats, individually and collectively, that they present.

The science currently best suited for this task is network theory:

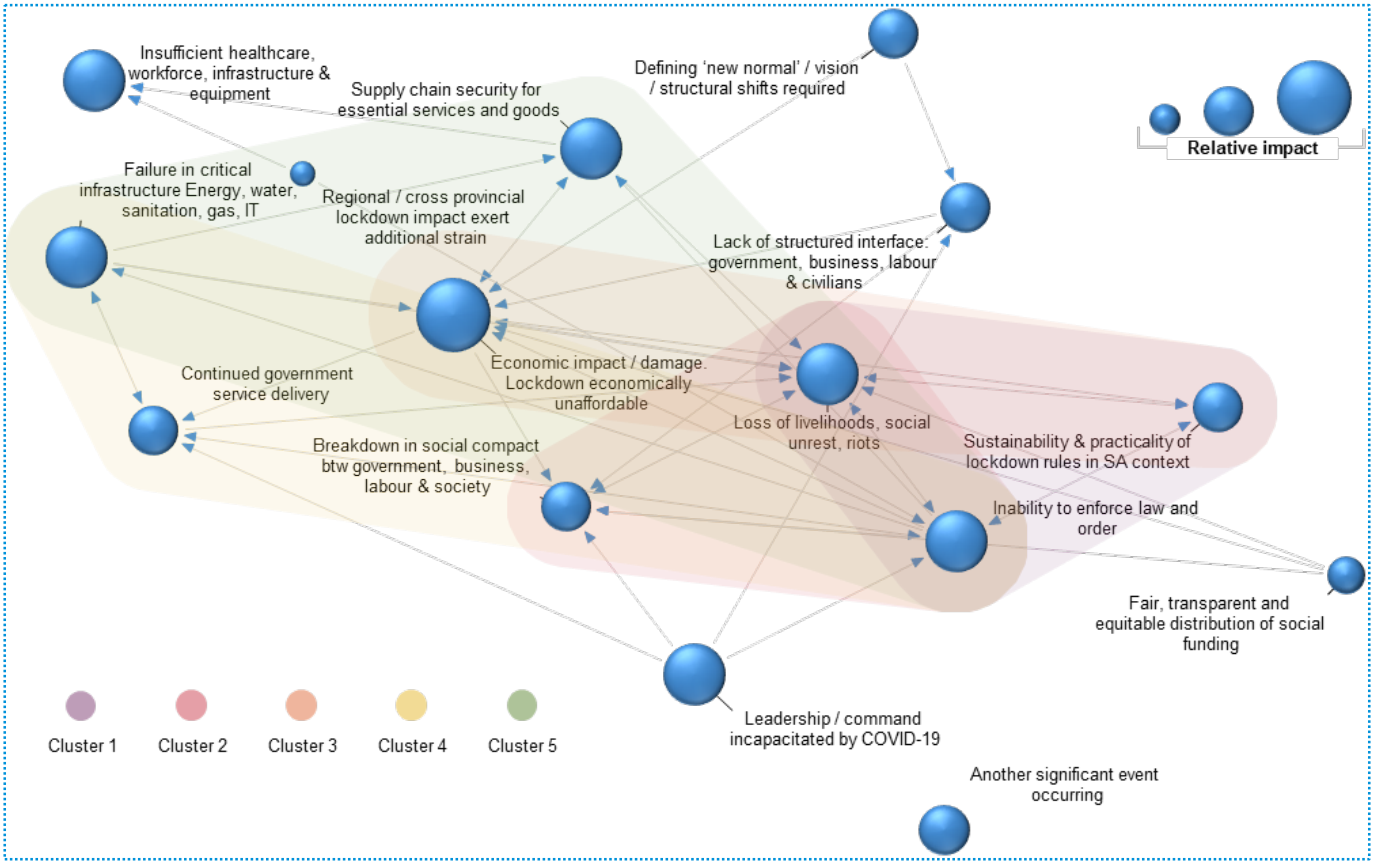
Figure 2: Causal linkages between discrete risks identified by participants through network theory



**The lines show the connectivity between risks and the arrowheads the strength and direction of the risk connection*

A networked analysis of the risks allows the identification of risk clusters; that is the combinations of risks most expected to occur in combinations by triggering each other if any one of them was to occur. The combinations identified are:

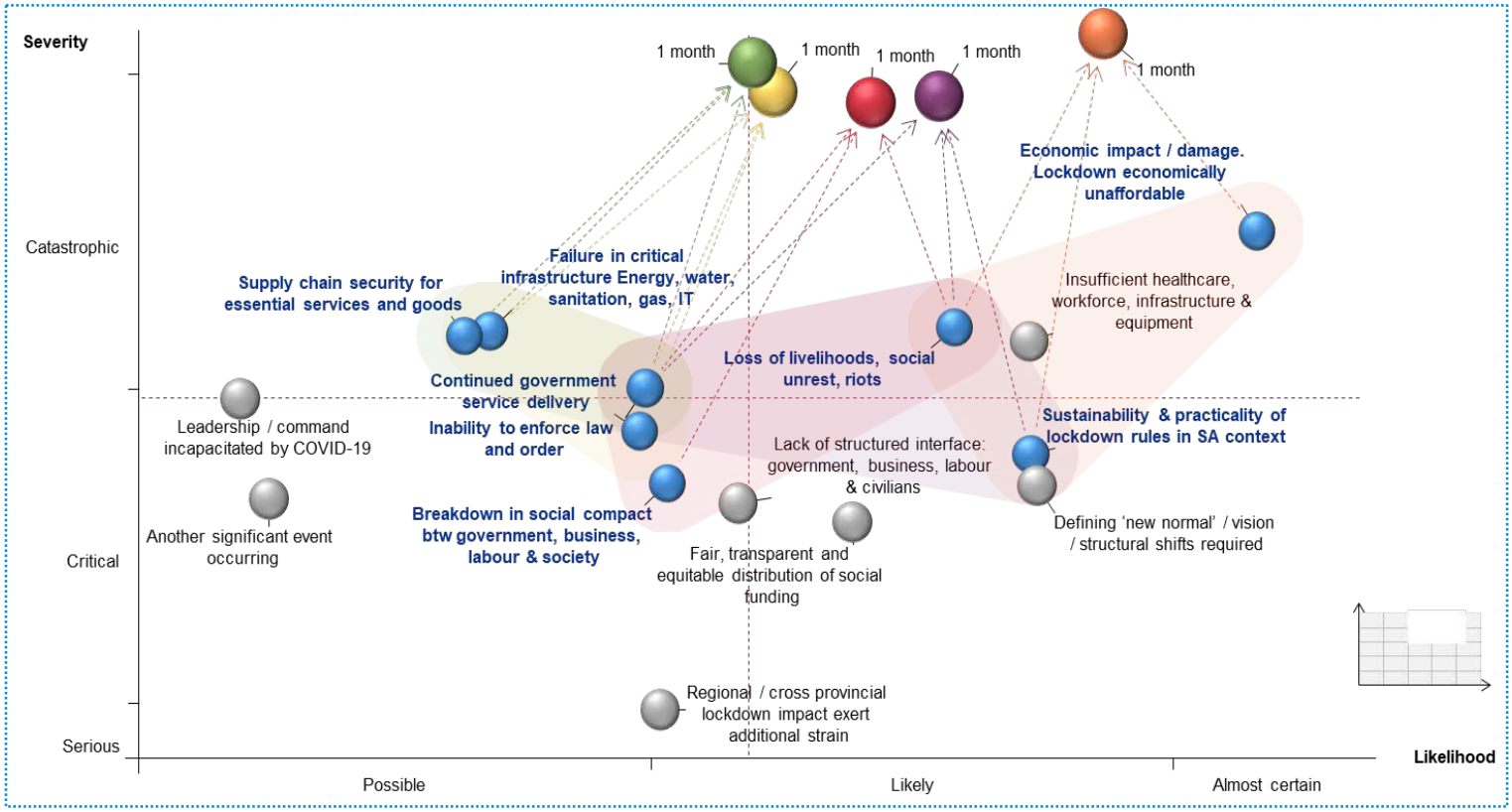
Figure 3: Clusters from network most expected to be encountered



**5 risk clusters defined on next page*

The risk clusters present the scenarios most expected to be encountered in future. They each have a **velocity of one month** – that is from the time any one risk in a cluster is triggered to the time that every risk in the cluster is triggered and their combined impact is felt, is one month:

Figure 4: Clusters of discrete risks most expected to occur together, and their velocities



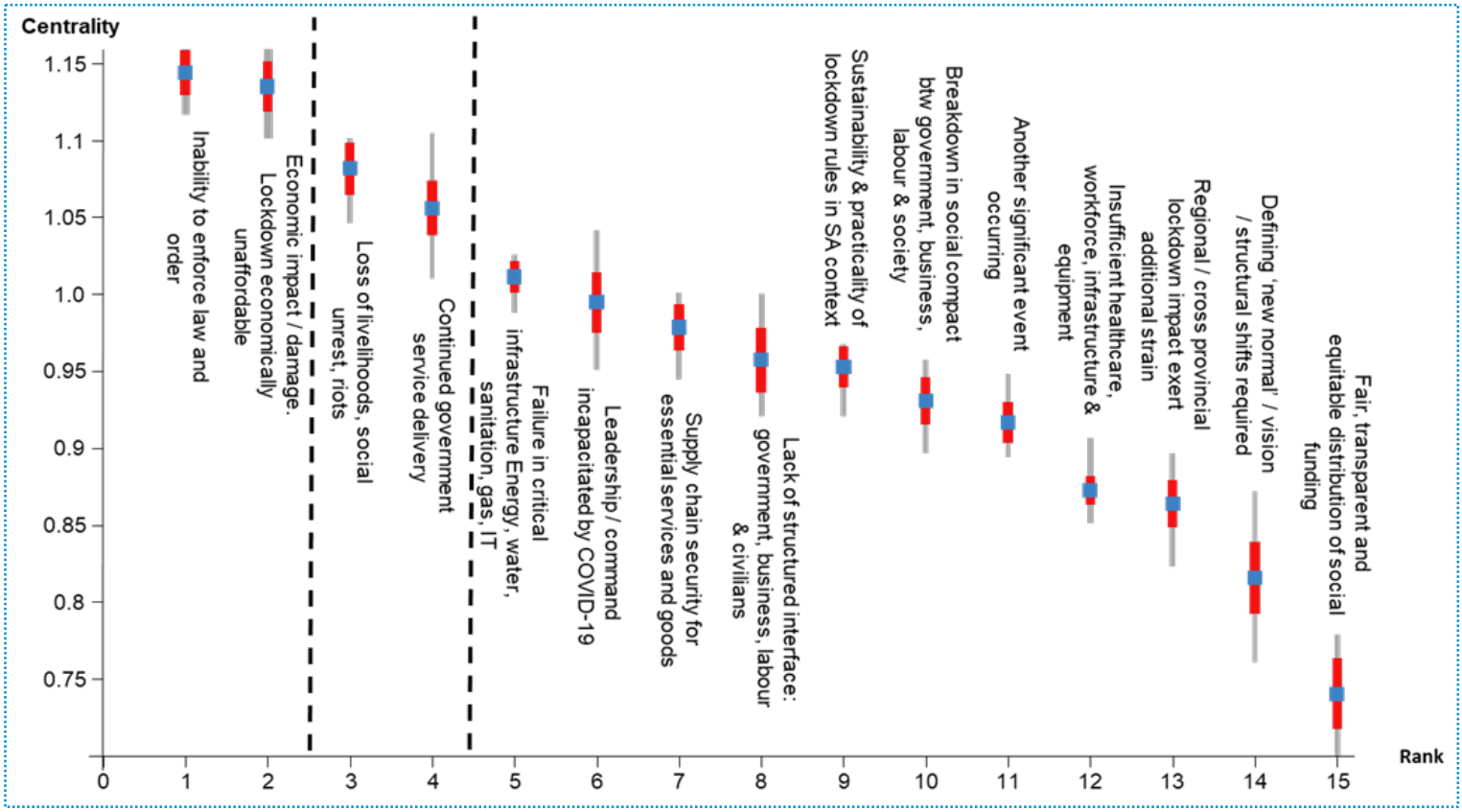
All five clusters have aggregate severities at catastrophic levels. The cluster with the highest expected loss and the greatest aggregate likelihood (almost certain) consists of ***Sustainability and practicality of lockdown rules in SA context; Loss of livelihoods, social unrest, riots*** and ***Economic impact / damage. Lockdown is economically unaffordable.***

The other four risk clusters include the risks of ***Sustainability and practicality of lockdown rules in SA context; Loss of livelihoods, social unrest, riots; Inability to maintain law and order; Breakdown in the social compact between Government, business, labour and society; Failure in critical infrastructure – energy, water, sanitation, gas, IT*** as well as ***Supply chain security for essential services and goods.***

With these scenarios most expected to be encountered in future, it raises the question of how they can be best prevented.

To answer this question most efficiently, we must take account of the interaction of all the risks onto each other. Again, network theory is helpful as it can identify the risks with the greatest flow-on consequences onto all the others:

Figure 5: Rank order of influencing effects of each risk onto every other risk



Inability to maintain law and order is the most central (systemically influential) risk. That is, it is the risk with the most powerful flow-on, pervasive causation onto every other risk. In other words, it is the single risk with the greatest 'reach' throughout the entire network of risks. Mitigate it, and it reduces the likelihood of every other risk being triggered - directly or indirectly – despite it not being in the most severe, most likely quadrant in the first graph. Its system-wide influence surpasses its individual threat level; potent as that is.

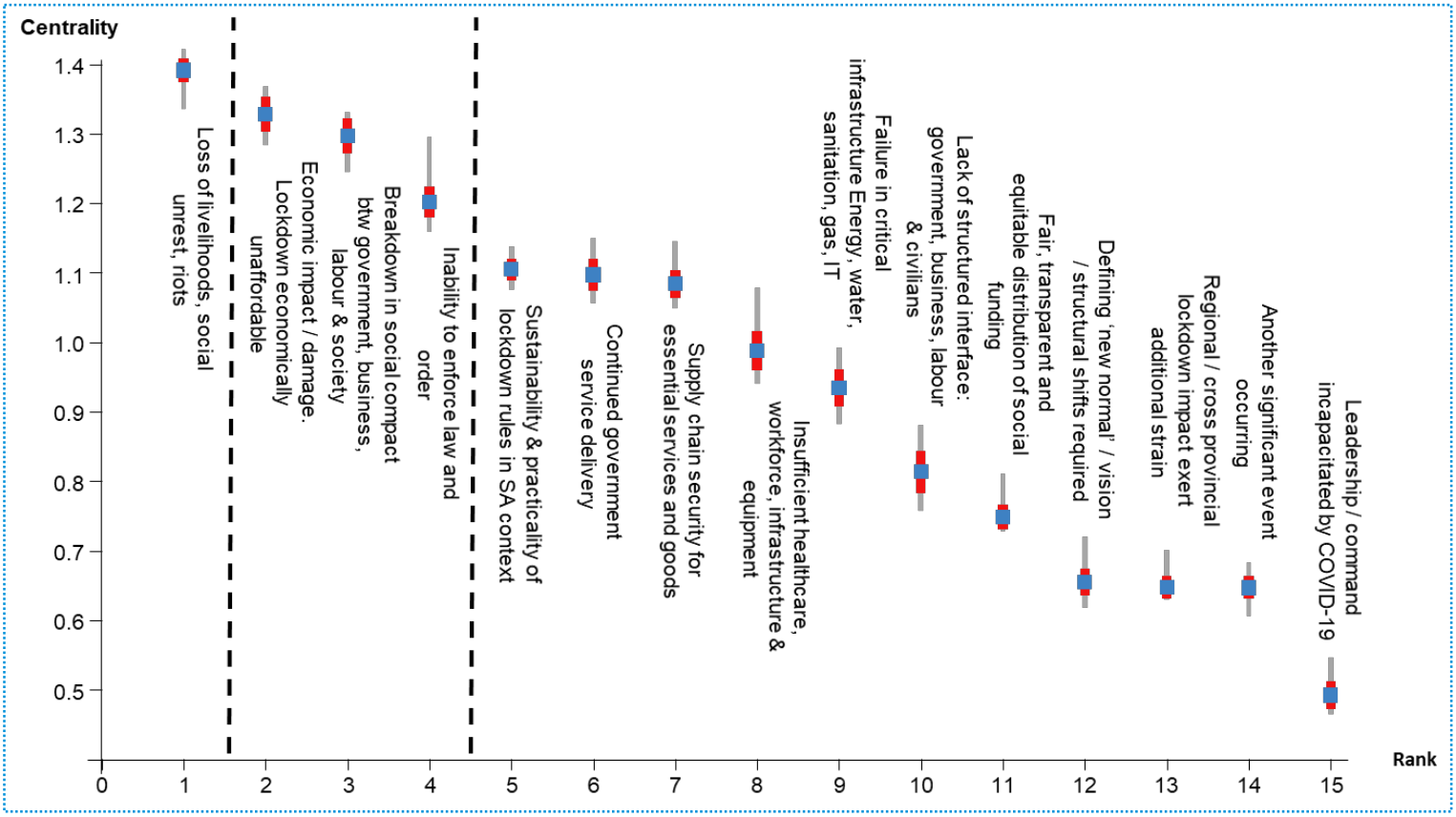
This means that the optimum mitigation of all the risks as components of a complex, adaptive system should start with the mitigation of *Inability to maintain law and order;* its individual mitigation will not be contained to it, but propagate maximally to every other risk with the greatest effect from all the options of where to start the mitigation of the risk environment.

Economic impact / damage. Lockdown economically unaffordable is the next most influential risk, followed by ***Loss of livelihood, social unrest, riots*** and ***Continued Government service delivery*** respectively. The level of influence drops after the latter risk.

Up to now the analysis has addressed the most threatening individual risks, the scenarios most likely to be encountered, and the rank order of mitigation that will most effectively permeate throughout the complex, adaptive system to reduce every risk with the maximum effect and pay-off on money spent.

However, it is now useful to let the collective contagion run its full course in order to see what the ultimate outcomes would be if no intervention takes place - the absolute worst case scenario as it were:

Figure 6: Rank order of vulnerability of each risk being influenced from every other risk



If the expected causation between the risks is allowed to run its full course, meaning there is no (or no effective) mitigation of the risks, or risk mitigation is focused on the 'wrong' risks, the ultimate result is expected to be ***Loss of livelihoods, social unrest, riots.*** The next 'domino to fall' will be ***Economic impact / damage. Lockdown economically unaffordable***, to be followed by ***Breakdown in social compact between Government, business, labour and society*** and ***Inability to enforce law and order.***

Were these risks allowed to occur at the same time, they will culminate into an existential, calamitous risk to the country. As a result, they simply cannot and should not be allowed to spread to each other. It is of the utmost importance.

With the optimal mitigation risks now identified, and the potential end outcomes articulated, it is time to consider the dynamics of the network of interconnected risks from its 'systemic beginning' to its 'systemic end':

Table 5: **Rank order of systemic influence and vulnerability of each risk**

Emitter rank	Emitter / influential risk (Risks with the most causal influence on other risks in descending order)	Receiver rank	Receiver / vulnerable risk (Risks most vulnerable / susceptible to flow-on effects from other risks)
1	Inability to enforce law and order	1	Loss of livelihoods, social unrest, riots
2	Economic impact / damage. Lockdown economically unaffordable	2	Economic impact / damage. Lockdown economically unaffordable
3	Loss of livelihoods, social unrest, riots	3	Breakdown in social compact between Government, business, labour and society
4	Continued Government service delivery	4	Inability to enforce law and order
5	Failure in critical infrastructure - energy, water, sanitation, gas, IT	5	Sustainability and practicality of lockdown rules in SA context
6	Sustainability and practicality of lockdown rules in SA context	6	Supply chain security for essential services and goods
7	Supply chain security for essential services and goods	7	Continued Government service delivery
8	Lack of structured interface - Government, business, labour and civilians	8	Insufficient healthcare, workforce, infrastructure and equipment
9	Leadership / command incapacitated by COVID-19	9	Failure in critical infrastructure - energy, water, sanitation, gas, IT
10	Another significant event occurring	10	Lack of structured interface - Government, business, labour and civilians

It is useful to start the analysis of this table with ***Economic impact / damage. Lockdown economically unaffordable.*** This risk appears as number two in both the influential and the vulnerability rankings. Meaning it is an unstoppable force of momentum; it will either propel an overall positive outcome, or it will pivot in an instant to impel a downward spiral all the way to the most vulnerable risk of all: ***Loss of livelihoods, social unrest, riots.*** As such, it offers no middle ground. Moreover, it can change from a force for good to a force for destruction in an instant, and without warning.

From the table on the previous page it can be seen that the number one concern for business is the wellbeing of people: ***Loss of livelihoods, social unrest, riots.*** It is defined as:

> "Inability to flatten curve extends lockdown. Cannot generate income / loss of livelihoods. Unemployment soars, mostly youth, high risk of social unrest / riots – may become political. Hunger, domestic violence, mental health, impact on education, civil disobedience. Business / property risk."

That is, it attracted a higher vulnerability (systemic concern) from business than the economy itself. Being systemically the most vulnerable, or collectively most susceptible risk, its optimal mitigation will come from the most influential risk: ***Inability to enforce law and order.*** Mitigating the latter risk therefore serves a three-fold purpose:

- It will optimally protect the economy which, in turn, will spread in a positive manner throughout the network to mitigate every other risk in the most efficient manner
- It will maximally safeguard the economy from pivoting to a negative, destructive downward spiral dragging every other risk with it into a calamitous, collective outcome
- It offers the best possible protection against people not being able to generate income, losing their livelihoods with employment soaring, mostly youths, triggering a high risk of social unrest / riots that may become political. Widespread hunger, domestic violence, mental health, impact on education, civil disobedience and business / property risk

Additional individual risks that are more influential in mitigating other risks than what they are affected by those risks (they appear higher in ranking on the left hand side of the table on the previous page than on its right hand side) include ***Continued Government service delivery, Failure in critical infrastructure - energy, water, sanitation, gas, IT***, as well as ***Lack of structured interface - Government, business, labour and civilians.***

These risks, then, are systemically mitigation accretive; they mitigate more than what is spent on their mitigation, to reduce the overall risks beyond their individual mitigation. As such, they present powerful levers to Government to combat the current situation with maximum effect.

Where do surprises in the network lurk? What can come from left field to disrupt a carefully balanced and poised situation? By analysing the network to identify the weakly linked risks with disastrous aggregate outcomes, the risk that was identified as a left field disruptor was ***Fair, transparent and equitable distribution of social funding.***

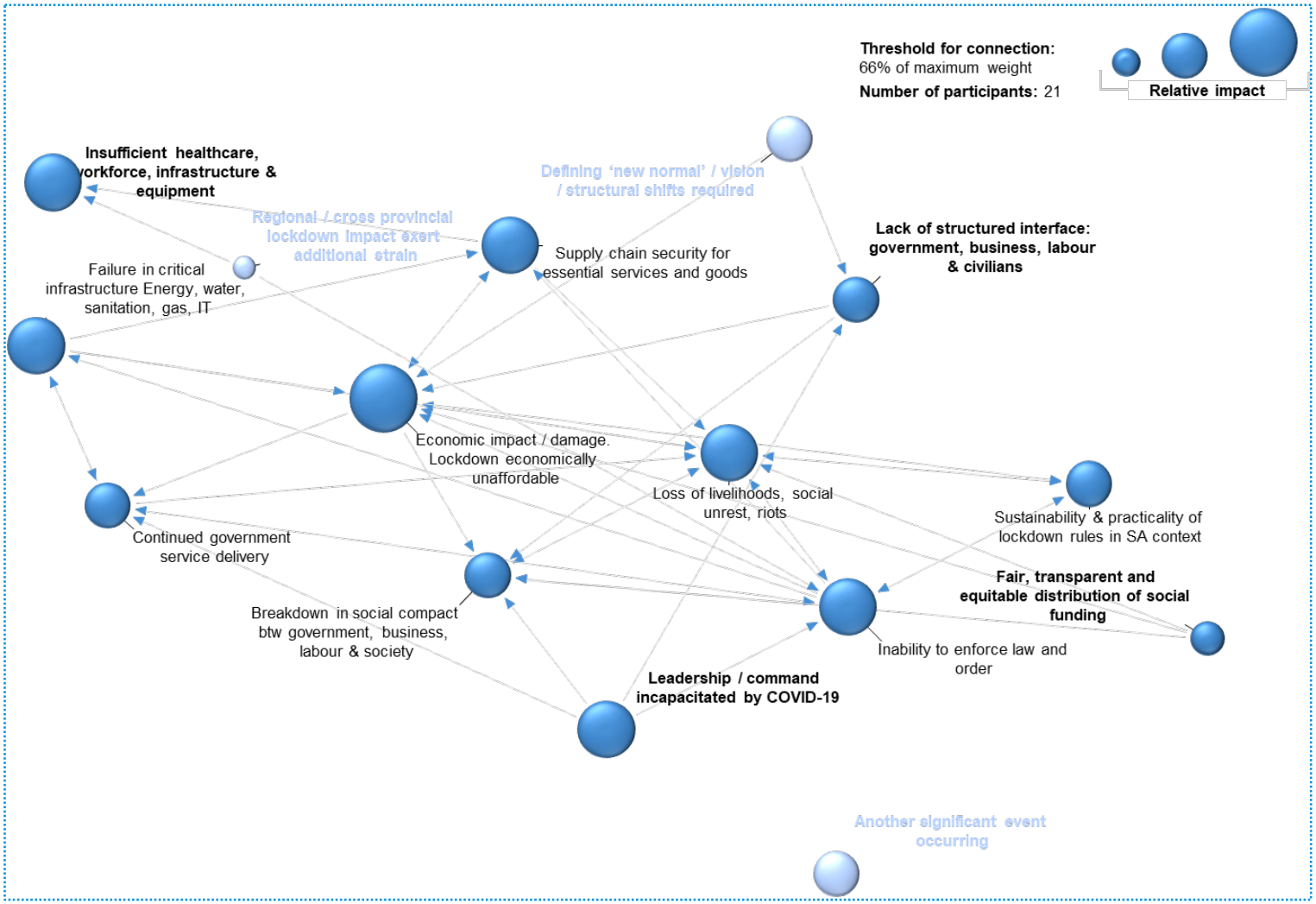
Specific attention should be paid to it: any impression, whether created by social media, rumour, innuendo or otherwise (even fake news) can trigger it, to trigger risks within the clusters identified earlier.

Which risks, or tendrils, are not

- Individually significant or likely?
- High in expected velocity?
- Highly connected, highly influential or influenced?
- Posing a strongly linked, high severity threat?

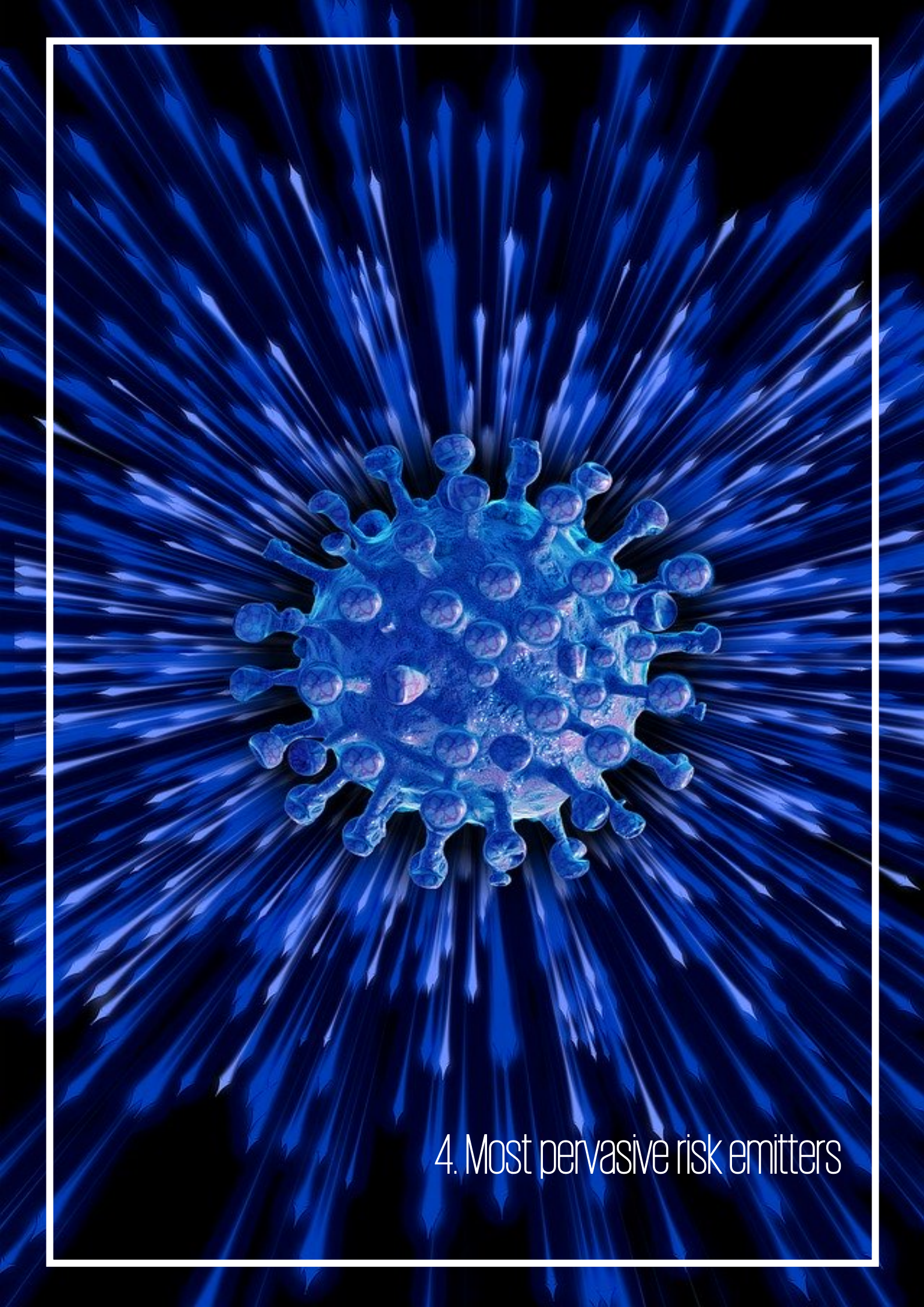
Or, to state it differently, which risks have not been caught in any of the analyses discussed so far?

Figure 7: Tendrils



The tendrils, or risks that are expected to be less connected (i.e. not systemically threatening), unlikely to be individually significant or likely, low in in velocity and not forming part of a weakly linked, severe outcome are ***Defining 'new normal/vision/structural shifts required; Another significant event occurring*** and ***Regional / cross provincial lockdown impact exert additional strain.*** These risks can be delegated and reported on by those entrusted with their mitigation. Not being individually or systemically important, they should not occupy the thinking of the highest levels of Government at this time.

Note that ***Insufficient healthcare, workforce, infrastructure and equipment*** was recognised as one of the top three risks in terms of being both catastrophic and likely. However, because it is not as central in the risk network in terms of connectivity, it may be best managed discretely by competent and capable healthcare leaders who are 'freed- up' to get on with managing this specific risk, whilst top leadership attends to ensuring the stability of the network.



4. Most pervasive risk emitters

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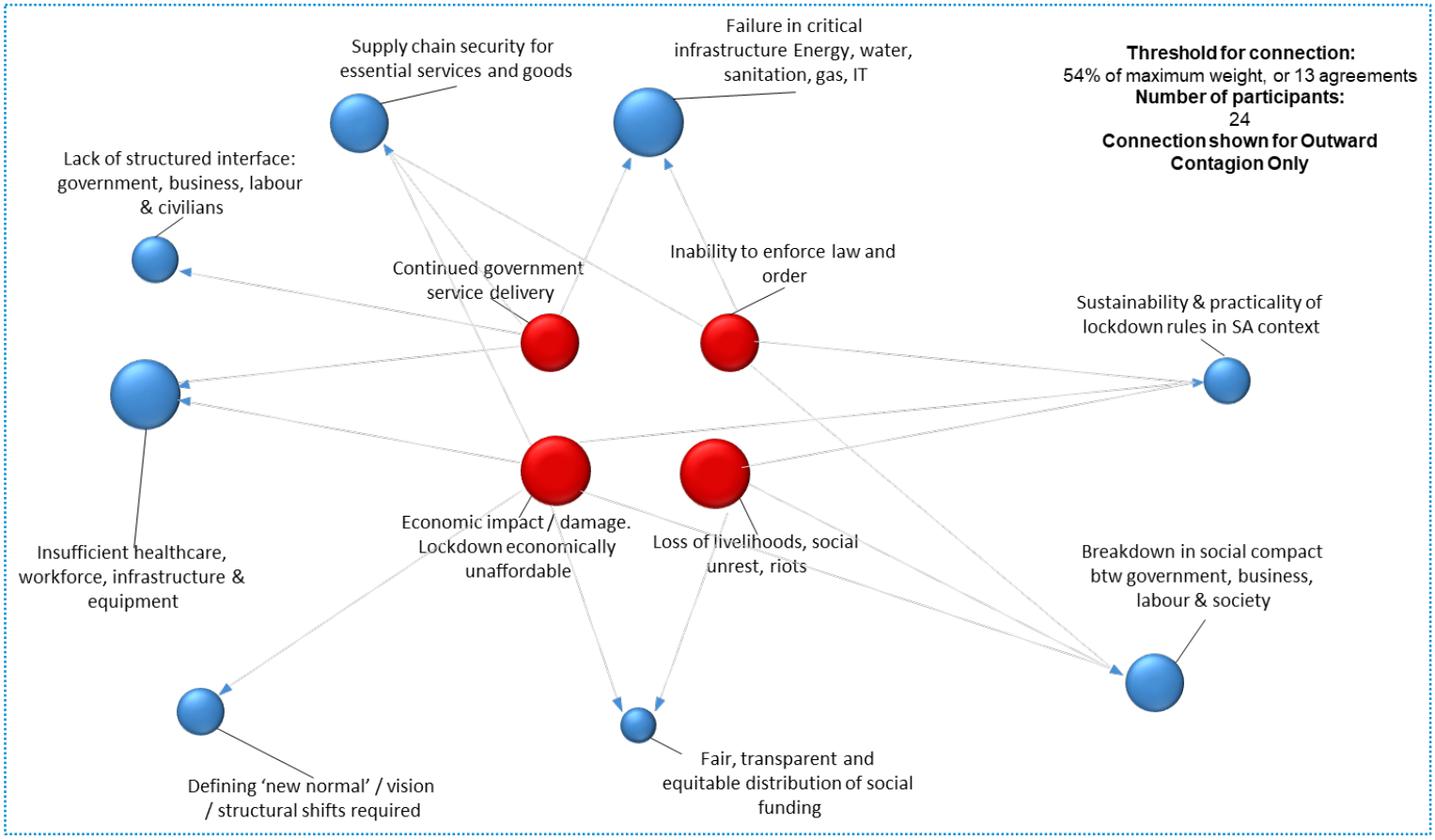
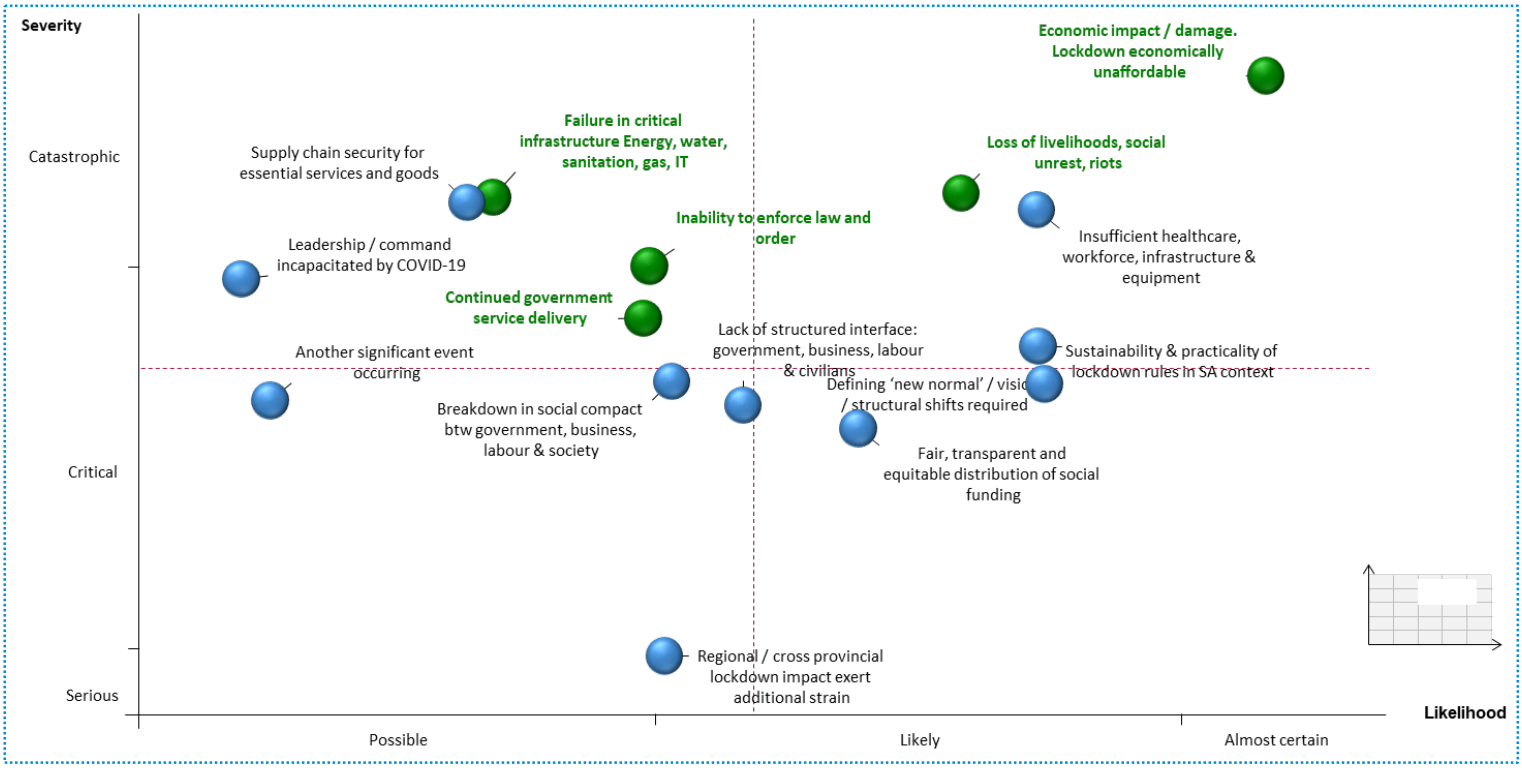
Figure 8: Illustration if the central risk emitters / most influential risks are not managed



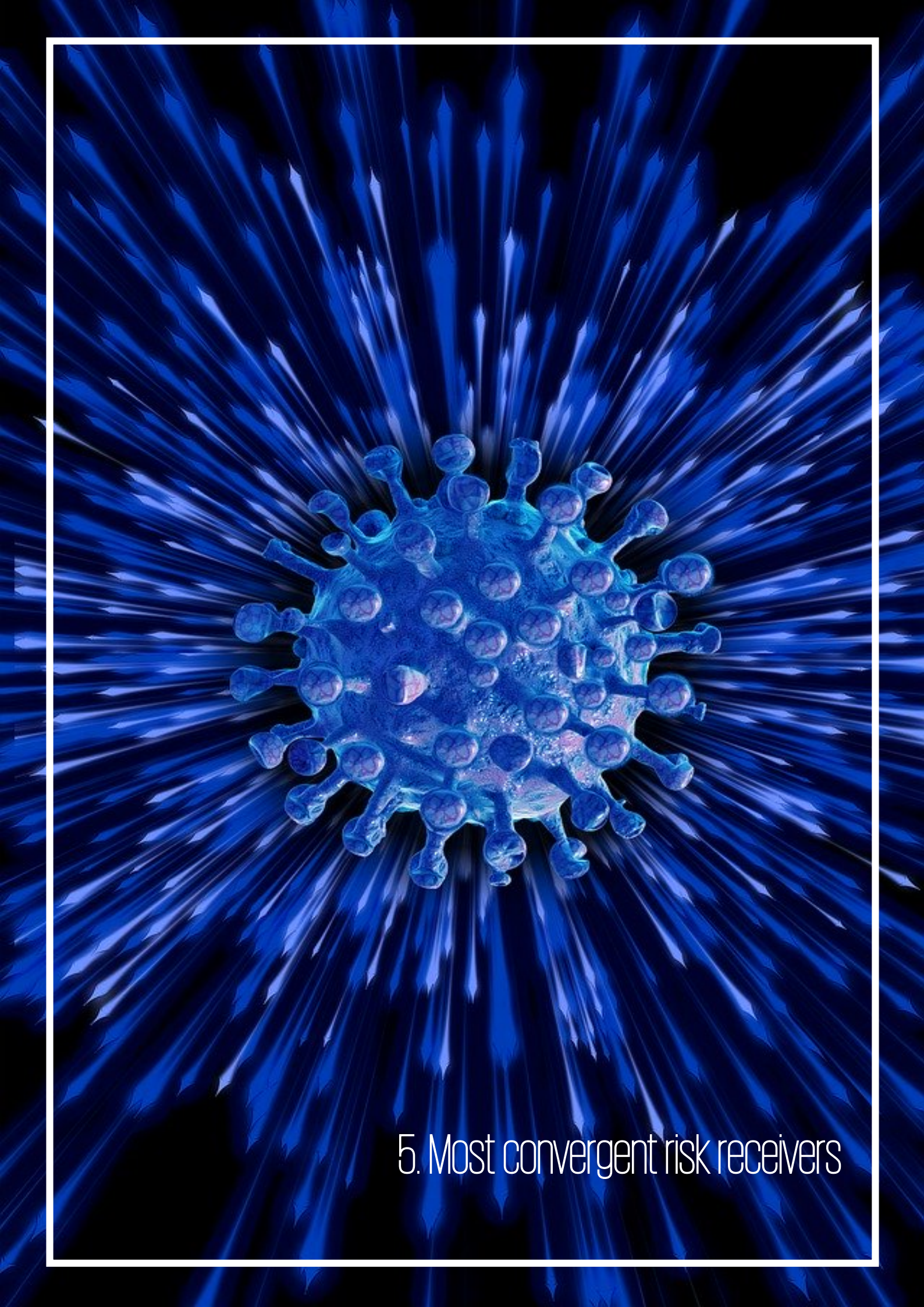
If the central risk emitters or the most influential risks (red circles) are not managed then there will be a flow through to other connected risks (blue circles).

Figure 9: The most influential risks according to their rank order



This graph shows where the central emitter / most influential risks sit on the **severity and likelihood graph.**

Under traditional Enterprise Risk Management (ERM) (without seeing connectivity and the network effect) it is possible that emphasis would be placed predominantly in top right quadrant as opposed to those risks in green which are the most influential risks in the network.



5. Most convergent risk receivers

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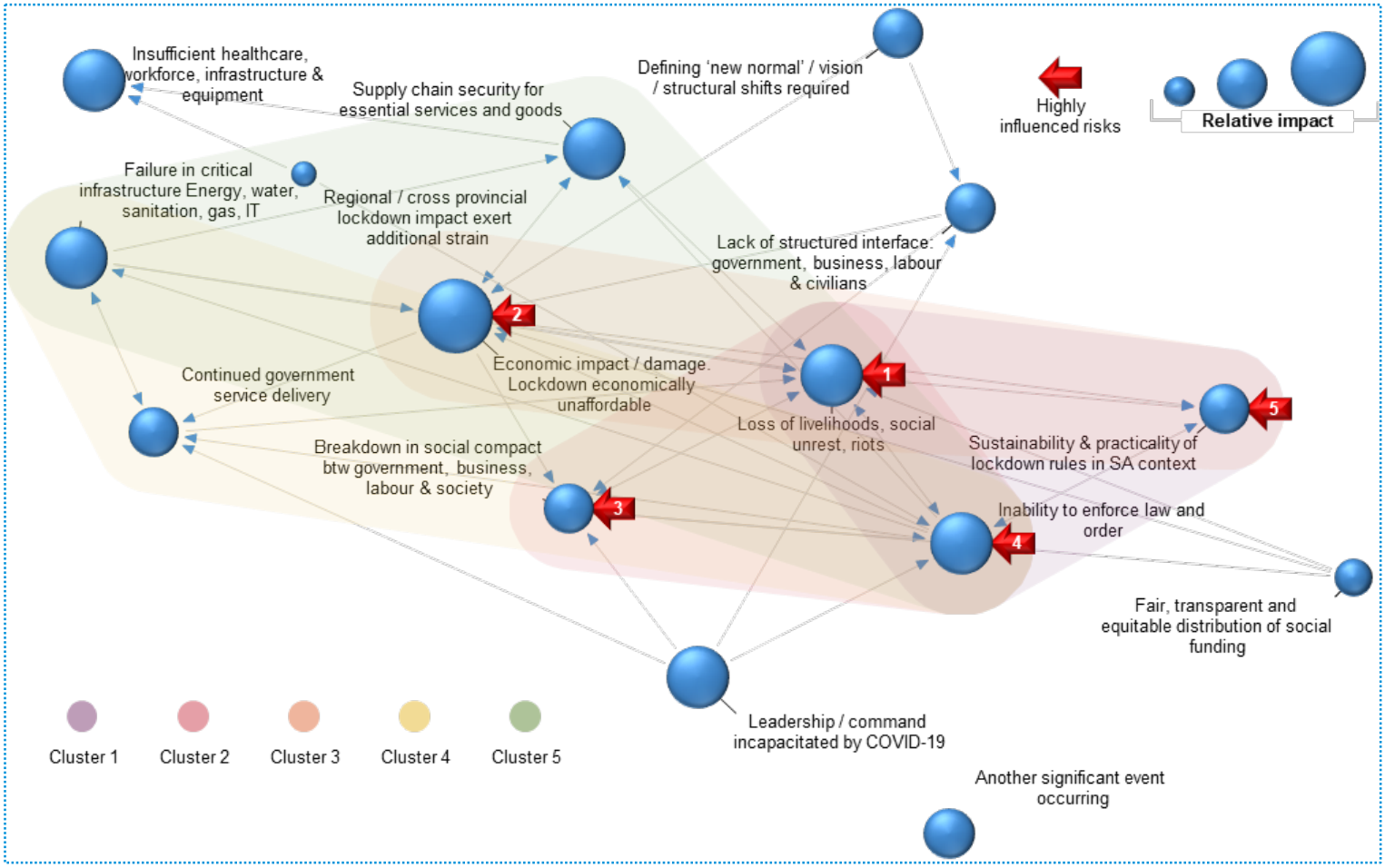
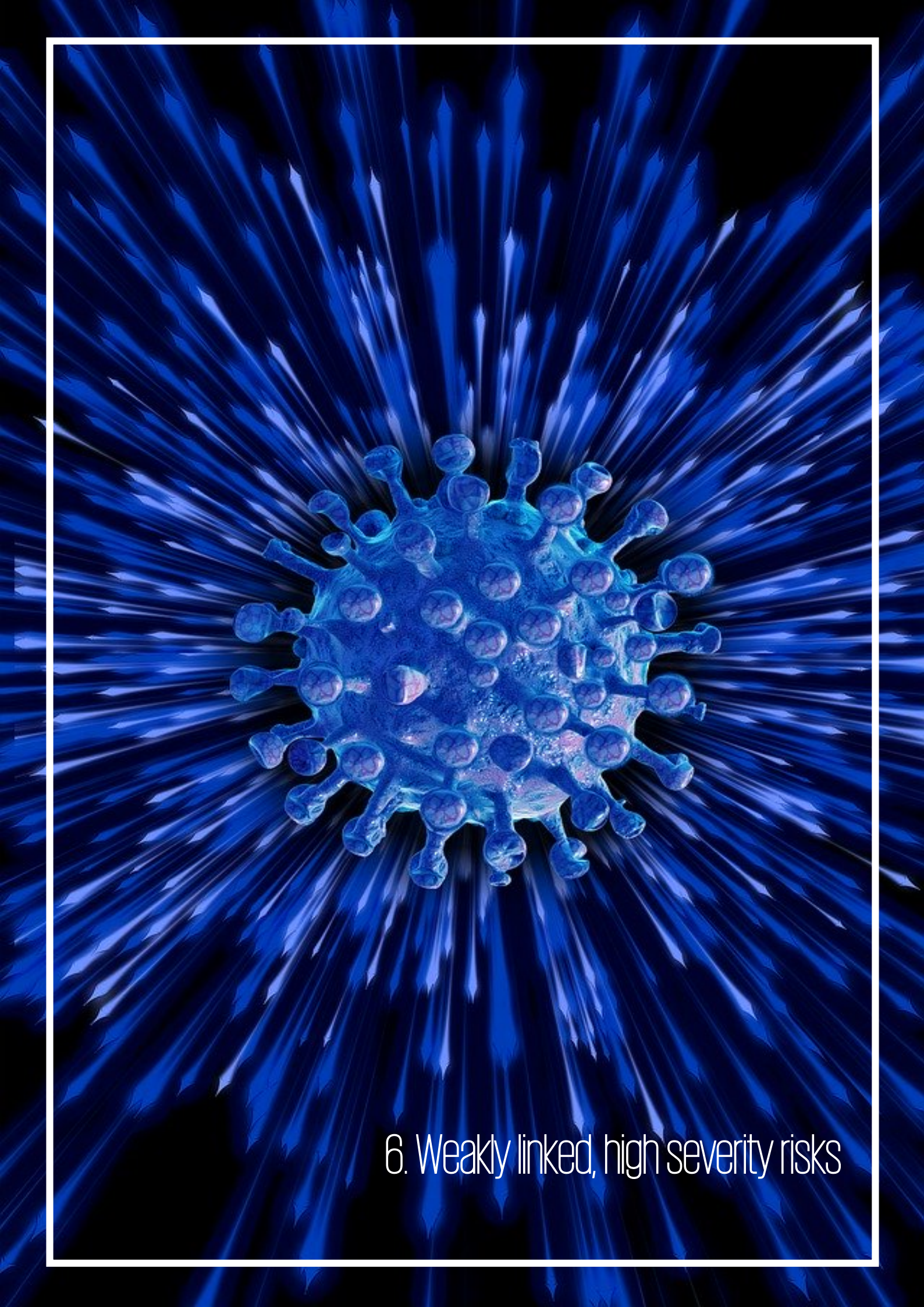
Correspondingly, when risks arise in the network, the most convergent risk receivers (or those risks most influenced or affected) suffer contagion. These highly influenced risks are shown in the network diagram below in numerical order i.e. the risk that is most influenced or impacted upon when other risks arise is ***Loss of livelihoods, social unrest, riots.***

Figure 10: Illustration of the most convergent risk receivers





6. Weakly linked, high severity risks

6. Weakly linked, high severity risks

Table 6: Weakly linked, high severity risks

Cluster	Risks	Threshold Percentage	Risk Rating
11	Breakdown in social compact between Government, business, labour and society, Economic impact / damage. Lockdown economically unaffordable, **Fair, transparent and equitable distribution of social funding,** Loss of livelihoods, social unrest, riots	0.52	0.54
25	Economic impact / damage. Lockdown economically unaffordable, **Fair, transparent and equitable distribution of social funding,** Loss of livelihoods, social unrest, riots, Sustainability and practicality of lockdown rules in SA context	0.48	0.59

One risk, ***Fair, transparent and equitable distribution of social funding***, not in the top five risk clusters, is weakly linked to risks in the top five clusters.

As such, if it is triggered, it can spread to a number of individual risks in the top five clusters, thus triggering a combined clustered outcome with catastrophic consequences.

It is analogous to an extreme (statistical) tail event, albeit it on a forward-looking basis.

It follows that the risk should be carefully managed / mitigated, so that it does not occur. Or, if it occurs, its contagion to other risks can be interrupted / severed decisively.

Appendices

A. Glossary

Term	Description
Dynamic risk assessment (DRA)	DRA methodology looks beyond the conventional two dimensional approach to depicting risk, typically based solely on grading individual risks according to their likelihood and severity, and takes a four-dimensional view by including considerations of risk interconnectedness and velocity. This enables consideration of the contagion effect of risk
Most convergent risk receivers	Risks most vulnerable / susceptible to flow-on effects from other risks These risks are significant in that they are triggered or made worse by other risks due to their centrality by effect
Most pervasive risk emitters	Risks with the most causal influence on other risks These risks are significant in that they have greater potential to trigger or make other risks worse in the network due to their centrality by cause
Risk clusters	Risk clusters are groups of risks that have been identified by the survey participants as particularly strongly connected and therefore should be considered in combination for risk management purposes
Tendrils	These risks are less significant in that they are individually benign and are neither systemically influential, or influenced
Traditional key risks	Based on severity and likelihood measures of risk
Velocity	Velocity measures the speed at which a risk is expected to have a material impact on onset
Weakly linked, high severity risks	Combinations of risks that display weak links to each other but pose disastrous aggregate severities

B. Network methodology

Background theory

The Global Financial Crisis (GFC) highlighted again that common risk management tools can be ineffective at forewarning company losses or failures. In our view this reflects several factors, including:

- Common risk management tools, such as risk registers, encourage organisations to focus on risks individually and do not capture the interconnections between risks. Research into company failures highlights that, typically, a number of related risks need to materialise for a company to suffer catastrophic loss or failure. Therefore understanding the connections between risks is necessary to prevent catastrophic losses / failure
- Common risk management tools often do not focus on risks that are systemically important. Systemic risks are those risks that are more likely to cause a cascading impact. Understanding systemic risks is important because these risks are more likely to be central to company failures and losses
- History indicates that the scenarios that cause catastrophic losses are unlikely to be the cause of the next catastrophic loss. This reflects a range of factors including changes to technology, globalisation and learning / adjustments from past events

Graph theory

Graph theory is the mathematical theory of graphs as a representation of pairwise relationships (termed *edges*) between pairs of (abstract) objects or *nodes*. Historically, it has been used in a number of different disciplines including physics, engineering and sociology. When graph theory is used as a mathematical structure to represent the causal relationships between risks, graph theory's formal methods provide

- A context with which to carefully define the systemic importance of risks and other topological features of the network
- Algorithms to determine the systemic importance of individual risks and the systemic features of the overall network
- A solution to the limitations of siloed approaches to risk management

Graphical representations of risk relationships are a feature of the annual World Economic Forum Risk Reports and in particular the Bank of England, and Federal Reserve have used graph theory to identify and analyse the connectivity between major risks. More recently, it has been applied to finance and, within this context, used to analyse the potential systemic relationships between individual risks.

Applying graph theory to survey responses

A number of valid approaches can be used to determine the graphical representations and statistics. Where alternative approaches exist, we have adopted an approach that, in our view, includes consideration of factors consistent with an application to risk management. For example, Bonacich Centrality has been adopted to measure the systemic importance of individual risks as it includes consideration of connections beyond the immediate connections (i.e. "flow-on impacts"). Further detail of the methodology adopted for each network measure is outlined in the sections where these measures are introduced.

A key challenge in applying graph theory to the survey responses is converting the responses into quantitative measures for each risk. The following approach was adopted:

- Only complete responses are included in the analysis to reduce the potential for bias within the results
- The connections are determined by summing the number of times another risk was identified as being made more severe or likely to occur by the risk in question. The systemic interconnectedness chart shows only those connections above a certain threshold determined to optimise the visualisation of the output, and to differentiate between "signal" and "noise"
- The responses from each participant for severity, likelihood and velocity are converted into values in the units of measurement using the risk scale calibration methodology (described in the following section) and each metric represented by an arithmetic average. For presentation in the charts, these averages are displayed in the same risk scales used to elicit the survey data

Limitations of approach

The user should acknowledge that graph theory is but one approach to analyse the key risks, and that other analyses may also be appropriate. Limitations of the approach adopted include:

- The analysis is based on survey data which represents the opinions of the survey respondents
- We have not independently verified the survey responses
- The approach adopted is based on one application of graph theory. Adopting alternative approaches may result in different results
- A range of analyses should be considered before making decisions

C. Risk scale calibration methodology

Overview of risk - Background theory

The collection of categorical data is very common in statistics. However categorisation of continuous data is often misapplied particularly in the case where the data has a natural significant level of numerical uncertainty. Used this way categorisation does not repair the issues of uncertainty but instead conceals it.

Where estimation has uncertainty, categorisation into bands has the effect of prematurely reducing the information content of the collected data. There are very few situations where *a priori* cut points are known for real valued variables and these unnecessarily imply discontinuous transitions in the phenomena studied. Under analysis this can lead to perverse situations where inference can be driven by the selection of cut points alone. It is for this reason Dynamic Risk Assessment explicitly collects continuously-valued risk metric data via an analogue-style interface.

The lines on the severity-likelihood plot and velocity collection interfaces acts as reference points such as on a ruler. The ability to smoothly move the position of points allows survey participants to consistently order all information, to re-visit earlier estimates, and throughout the process have a visual summary of their responses. The random ordering of risks with respect to every participant reduces any systematic data quality effects due to survey fatigue.

Log-linear risk scales

Recent research suggests that in the absence of formal mathematical education the human conceptual interpretation of numbers naturally default to a logarithmic description. This is not surprising as the *Weber-Fechner Law* suggests that this may have a biological origin with the senses of brightness, sound, pain and chemical response in biological systems also being logarithmic. In addition this may have evolved because of all categorisation schemes it is the unique one which reduces relative error in magnitude estimation. Consequently only scales similar to these allow survey participants of all numerical abilities to estimate risk metrics consistently over the many orders of magnitude difference in event rate and severity usually encountered in enterprise risk management. Serendipitously the use of expected loss as a determinant in risk-based pricing and actuarial theory mathematically support the use of logarithmic risk scales.

Historically, the use of logarithmic scales for the depiction of risk magnitude is not exclusive to KPMG. Log-risk scales are also a common practice in risk modelling in Engineering. Even so, the principle scientifically-supported benefit of the KPMG methodology is that log scales collect better data from expert participants in addition to increasing their comprehension when depicting it to them.

Client specific risk scales

Informed by the breadth of the client's own risk scale a logarithmic risk scale can be defined specifically for them. The survey tool then allows the survey data to be collected calibrated to this standard ruler as informed by the client's own risk measurement methodology or policies, or where absent a best practice proxy scale provided.

D. Risk cluster scoring methodology

Risk clusters - principles

In graph theory groups of strongly related risks are called risk clusters. These are relevant because company losses / failures are typically the result of a number of related risks materialising at the same time.

Risk clusters are determined by analysing a number of factors, including strength and number of connections between a small group of risks. All risks within a cluster are likely to trigger / make more severe or be triggered / made more severe by other risks in the cluster.

Risk clusters

Risk clusters are determined using the following approach:

– An algorithm identifies potential risk clusters based on a subset of risks that meet minimum criteria. It may identify multiple clusters with similar risks. For example, one potential cluster could be identified with four risks while another potential cluster could be the same four risks plus another risk

Risk cluster score aggregation

There are a number of alternative approaches in graph theory to aggregate risk nodes and produce an aggregate risk score for a risk cluster. However, there is no universally accepted approach when non-parametric, ordinal risk ranking scores are used.

E. Reliance and limitations

Inherent limitations

This report has been prepared as outlined in the Background and Scope Section. The services provided in connection with this engagement comprise an advisory engagement which is not subject to Auditing Standards or Standards on Review or Assurance Engagements, and consequently no opinions or conclusions intended to convey assurance have been expressed.

The findings in this report are based on data output from the survey undertaken by B4SA.

No warranty of completeness, accuracy or reliability is given in relation to the statements and representations made by, and the information and documentation provided by respondents. In particular, we have not independently verified the survey data responses.

KPMG has indicated within this report the sources of the information provided. We have not sought to independently verify those sources unless otherwise noted within the report.

KPMG is under no obligation in any circumstance to update this report, in either oral or written form, for events occurring after the report has been issued in final form.

The findings in this report have been formed on the above basis.

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