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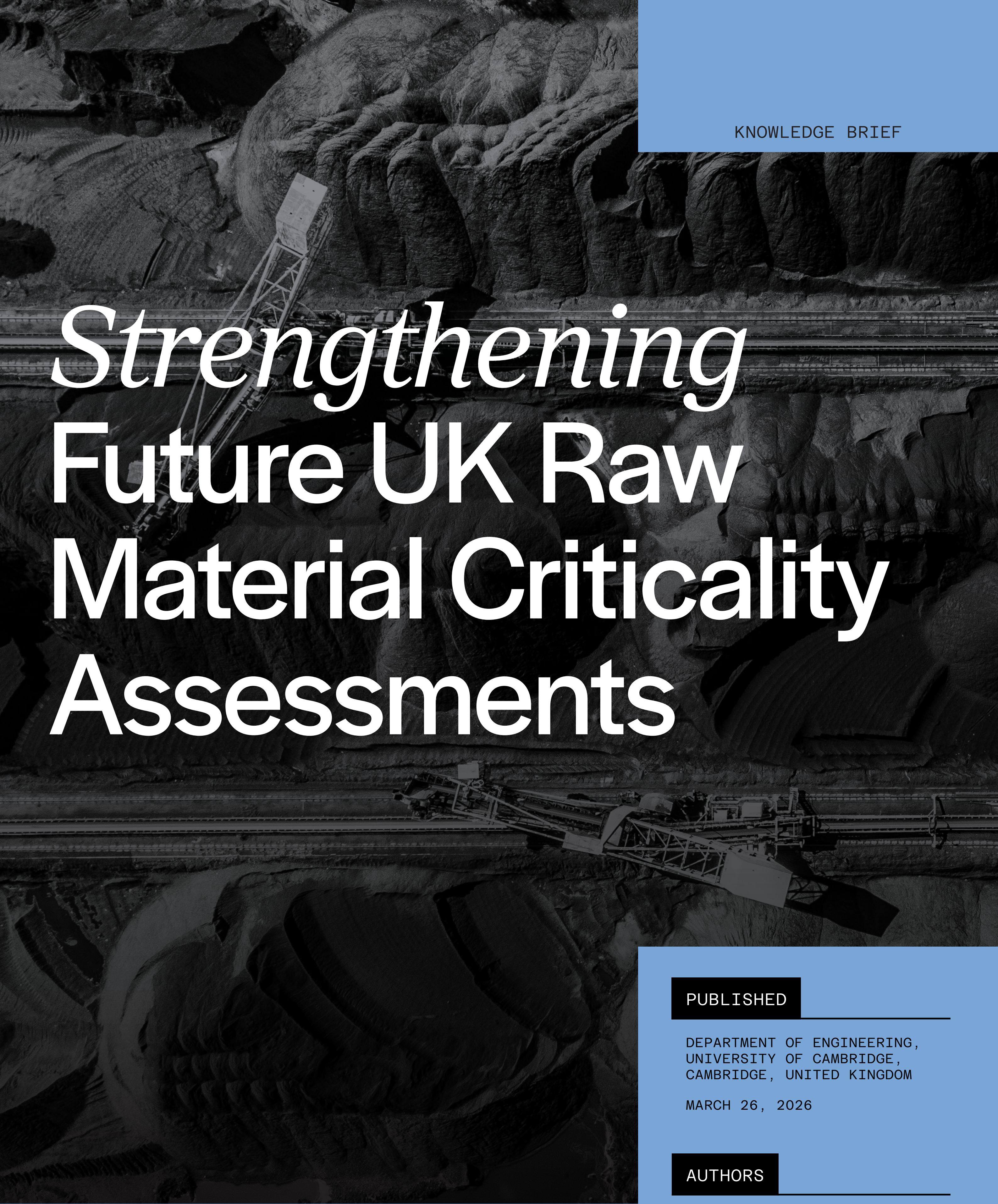

Strengthening Future UK Raw Material Criticality Assessments

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EXECUTIVE SUMMARY

A criticality assessment is a means of prioritising policy attention between a set of raw materials. In practice, it ranks materials by considering how likely disruptions are to a supply chain and how serious their consequences would be for a defined subject over a defined period. In this brief, that subject is the UK. Critical material supply disruption is a strategic concern for the UK because the country depends heavily on imported raw materials and on extraction, processing, manufacturing, and logistics systems located abroad. These disruptions can arise from mine or refinery outages, export controls, social conflict, infrastructure failures, shipping disruption, or broader shifts in supply and demand.

The UK's current methodology is a useful screening tool. It can prioritise attention across a wide range of materials and support near-term monitoring and policy discussion. It is also more sophisticated than many official indicator-based frameworks. Yet screening tools remain limited. They do not by themselves identify defined disruption scenarios, estimate resulting economic losses, or show which intervention would reduce those losses most effectively. Their results depend on proxy indicators whose relationship to actual disruption processes is imperfectly established, and they compress different hazards and supply-chain stages into a small number of broad scores.

In the longer run, the UK should move toward simulation-based criticality assessment. This approach is better suited to policy because it can define explicit disruptions, trace their propagation through supply chains, and express consequences in decision-relevant units. That transition will take time. Existing simulation methods still face limits in hazard coverage, data requirements, and modelling detail. The recommended path is therefore phased: improve screening tools now, while building the data, hazard definitions, and likelihood models needed for future simulation-based assessment. Predictive modelling of disruption likelihood is the clearest bridge between these two approaches.

Key Recommendations

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The UK's current criticality assessment is a useful screening tool, but it cannot by itself identify defined disruption scenarios, estimate resulting losses, or show which intervention would reduce those losses most effectively.

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In the long run, the UK should move toward simulation-based criticality assessment. This approach is better suited to policy because it can represent explicit disruptions, trace their propagation through supply chains, and express consequences in decision-relevant units.

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That transition will take time. Existing simulation-based methods remain narrow in hazard coverage, demanding in data, and incomplete in several key respects.

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Screening tools should therefore continue to be improved in parallel. This work also supports the longer-term transition to simulation-based assessment. Some of the same tasks, especially clearer hazard definition and stronger modelling of disruption likelihoods, are needed both to improve screening and to support later simulation.

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Predictive modelling of disruption likelihoods is the clearest bridge between the two approaches. Where defensible likelihood models can be built, they can strengthen screening tools now and later support simulation-based consequence analysis.

Introduction: Criticality and Criticality Assessments

Critical minerals underpin the UK's energy transition, national security, economic resilience, and the functioning of electricity networks, transport systems, digital infrastructure, advanced manufacturing, defence applications, and health technologies. The UK is exposed to disruptions in these supply chains because it imports many of the materials it depends on and relies heavily on extraction, processing, manufacturing, and logistics systems located outside its territory. Such disruptions can arise through mine or refinery outages, export controls, social conflict, infrastructure failures, shipping disruption, or more gradual shifts in demand and supply. That exposure is heightened by structural features of the UK economy: limited domestic geological endowment, an import-dependent service economy, and less bargaining weight than larger geo-economic powers. For the UK, material supply disruption is therefore a strategic concern.

A criticality assessment evaluates how likely defined disruptions are to a material supply chain, and how serious their consequences would be for a defined subject over a defined period. In this brief, that subject is the UK. Criticality is therefore not a universal property of a mineral, but it varies in relation to a particular subject, a particular kind of disruption, a particular time horizon, and a particular measure of harm [1, 2, 3]. Different consequence metrics may be legitimate for different policy purposes. For many UK decisions, the most immediate one is economic loss. Human and environmental impacts also matter, including impacts in producing countries, but they should not be collapsed into a single score unless the government makes the underlying trade-offs explicit.

The UK already uses criticality assessments in practice. The Critical Minerals Intelligence Centre's (CMIC) 2024 assessment provides the main quantitative screen for current conditions, while Vision 2035 adds a forward-looking Growth Minerals List. UK Export Finance links parts of its support offer to the CMIC list and to a limited set of growth minerals, showing that list design can feed directly into policy support [4, 5, 6]. The wider UK debate also extends beyond supply acquisition to recycling, material efficiency, and demand reduction [7]. Assessment design therefore matters for deciding where public attention and public support are most justified.

The criticality assessment landscape is currently divided between methodologies which are high-coverage but imprecise, and those which are narrow but precise. This brief provides the necessary context to understand these nuances, and provides a practical path forward for reconciling the trade-offs between the two approaches; ultimately allowing the UK to maximise its intelligence in the competition for critical materials, and position itself to allocate fiscal resources with target precision.

2. The Importance of Criticality Assessments in Policy

Official raw material criticality lists influence policy choices. Across jurisdictions, they are used to help steer subsidies, public finance, stockpiling, permitting, procurement, trade measures, and other forms of state support [8, 9]. Once a mineral enters an official list, this can affect which supply chains receive sustained monitoring, which projects are treated as strategic, and which forms of intervention are easier to justify politically.

This is already visible in the UK. CMIC's 2024 assessment provides the main current-risk list, while Vision 2035 extends the policy frame through the Growth Minerals List for minerals linked to future strategic sectors. UK policy therefore already distinguishes, at least in practice, between present supply risk and future strategic importance [4, 5, 6].

Because these lists shape real policy decisions, the quality of the assessment method matters. List membership alone does not tell policymakers what kind of problem they are dealing with. A material can be judged important because mining is concentrated; refining is concentrated; a firm or facility is a single point of failure; inventories are low; demand is concentrated in a strategic downstream use, or because several of these conditions coincide. These are not the same situations, and they do not point to the same response. A useful assessment therefore does more than identify which materials warrant attention. It also helps distinguish the source of concern, so that responses such as stockpiling, diversification, recycling, substitution, or domestic processing can be better matched to the problem.

3. Context: The Global State of Criticality Assessment

3.1. The Two Approaches to Criticality Assessments

Criticality methods differ because different actors face different decisions. A national government may ask which supply disruptions would damage economic output, defence capability, or strategic objectives. A firm may ask which inputs threaten a particular product line. A technology assessment may ask which minerals constrain deployment. Differences of perspective can therefore justify differences of scope, time horizon, and consequence metric [2, 10]. Official methods are also unevenly published. Some jurisdictions disclose full methodologies, others publish only lists, and in many cases public methodological detail remains limited [9].

The existence of different perspectives does not, however, imply that all methods are equally informative once the assessed subject and consequence metric are fixed.

For instance, the following principles, if adhered to, lead to a more rigorous and informative final result: First, the clear communication and justification of what kind of disruption (or disruptions) is being considered, how likely it is, how it would propagate through the supply chain, and what form of harm it would generate for the chosen subject. In other words, it should distinguish the disruption itself, the pathway through which it reaches the assessed subject, and the resulting consequence. Second, a clear communication of the kind of consequence that is being assessed. If the consequence is economic loss, the result should be interpretable in economic units. If the consequence is environmental or human harm, the result should carry those units instead. Combining different harms into a single score is a further normative step which requires explicit value judgements and could not be justified being treated as an objective output of the model [10, 11].

These principles provide a clear lens through which existing criticality assessments can be evaluated; with current methodologies separating themselves into two broad camps.

3.1.1. INDICATOR-BASED ASSESSMENTS: THE UK'S POSITION

The first camp of methodologies build their assessments from indicators, such as production concentration, import dependence, recycling rates and governance indices. The values of these indicators, once combined, are treated as proxies for either the likelihood of a disruption event occurring, or its consequence.

The result is a score for each raw material, which then allows the 'critical' materials to be separated from the non-critical, usually by applying a criticality threshold. This allows broad coverage of materials, but does not aim to provide high-resolution insights for target intervention. As such, this brief terms these 'screening tools'. These are useful screening proxies, but they do not by themselves identify a specific disruption pathway, and they provide only limited guidance on which intervention would reduce the resulting concern most effectively [12, 11].

Compared with many official screening frameworks, the UK methodology is a relatively sophisticated indicator-based approach. The CMIC 2024 assessment evaluates 82 candidate materials and identifies 34 as critical using two headline dimensions, global supply disruption likelihood and UK economic vulnerability [4]. It is also more explicit than many official lists about the criteria used to derive its results [9]. Unlike frameworks that rely on rigid rectangular thresholds, such as the EU approach [3], it uses convex isocritical contours, which provide a more continuous representation across the score space and reduce abrupt reclassification near cut-offs [4]. The framework is tailored to the UK economy and is explicit that it provides a snapshot of recent conditions rather than a full forward-looking model. Future demand is addressed separately through foresight work and the Growth Minerals List in Vision 2035, so present vulnerability and future strategic demand are already treated as distinct but related questions [4, 5].

As with any indicator-based screening method, however, there remain limitations.

Screening tools, relying on proxy indicators, such as production concentration, governance scores, reserve metrics, or recycling rates, often lack the empirical data to prove relationships between those indicators and actual disruption processes. Secondly, they compress a long causal chain into two broad indices, which can mix disruption likelihood, exposure at source, propagation through trade, and downstream susceptibility within a single score. Thirdly, many published results say too little about what the score is actually meant to represent. That ambiguity makes the output difficult to interpret. It also makes it harder to compare the score with the costs of possible interventions, especially when the result is not expressed in a unit that corresponds clearly to the harm being assessed. Fourthly, broad country-level indicators can miss risks that sit at other points in the supply chain, including specific firms, facilities, processing stages, or transport links. A screening tool may therefore identify that a material deserves attention without showing clearly where the main source of risk lies.

In the case of the UK, the current score does not directly identify which hazard has been approximated, which stage of the supply chain is driving concern, how inventories and timing would alter the picture, or how large the resulting UK loss might be under a defined scenario. It also depends on proxy indicators whose empirical relationship to the underlying dimension is often weakly established. Production concentration, governance conditions, recycling rates, co- or by-production, or trade shares may all be informative, but they are not the same thing as disruption likelihood, propagation, or consequence, and they are not always shown to predict those dimensions reliably. A related issue concerns aggregation within each dimension. Once several indicators are combined into a single score, the result depends on assumptions about weighting, substitutability, and functional form. Those assumptions are not always easy to justify from the underlying disruption process. The framework also has limited ability to distinguish whether the main source of concern lies in extraction, refining, firm- or facility-level concentration, logistics, or downstream dependence in a strategic use. These are the kinds of questions that future assessment rounds could address more clearly within the screening framework, and that more focused studies could examine in greater detail for selected cases.

As such, the UK's current standing is at the stronger end of screening tool assessments, but it has not broken free of the method's inherent limits.

3.1.2. SIMULATION-BASED ASSESSMENTS

The alternative paradigm of criticality assessment is simulation-based. Rather than inferring disruption consequence from static proxy indicators alone, this approach draws on the input-output disaster-modelling literature, which represents the economy as a set of interdependent industries and estimates how a shock in one part of the system constrains production elsewhere [13, 14]. In practical terms, input-output analysis can translate a shortfall in a mineral input into downstream production losses and, eventually, into economy-wide economic effects. Adapted to raw materials, this allows criticality analysis to move from broad screening proxies toward explicit disruption scenarios and quantified economic consequences [15, 16]. Later work strengthened this approach by introducing trade-network structure, mineral-specific elasticities, inventory adjustment, and excess-capacity responses, thereby bringing it closer to the short-run behaviour of disrupted supply systems [17, 18].

A major step in this direction was taken in the United States, where the 2025 U.S. Critical Minerals List (USGS) is based on a simulation framework. The 2025 USGS methodology defines explicit trade-disruption scenarios for each mineral, estimates the resulting supply shock using trade, production, and elasticity data, propagates that shock through an input-output model of the U.S. economy, and converts the result into a probability-weighted GDP loss [19]. This is a substantial methodological step because the main output is expressed in dollars, which makes it more directly comparable with the annualised cost of mitigation options [19]. A separate criterion also flags single domestic producers as concentrated vulnerabilities [19]. Scenario probabilities are assigned either directly, in cases where export controls are already in force, or through a machine-learning classifier trained on historical trade barriers and market-structure covariates [20, 19]. The present U.S. framework still has important limits. It focuses mainly on trade-restriction hazards, assumes a one-year full-cutoff form, and does not capture all non-trade disruptions or all third-country ripple effects [19]. Even so, it shows that scenario-based consequence analysis can be operationalised for official policy use [19].

4. Potential Paths Forward

The two criticality paradigms offer distinct trade-offs. Indicator-based screening tools allow broad coverage across materials, but suffer from inherent limitations due to their lack of resolution – they are a 'broad strokes' approach. Whereas simulation-based assessments are more precise, allowing for more directly targeted intervention, but suffer from a high data and resource requirement. Research gaps remain which suggest that simulation-based assessments may not be fully mature, and therefore may be restricted in scope for a number of years.

Thus, a fundamental tension exists in determining the UK's methodological trajectory: whether to maintain the breadth of the indicator-based framework despite its lower resolution, or to adopt the emerging simulation-based frontier despite its current limitations.

4.1. Incremental Improvement within the Screening Approach

While the UK's current methodology is positioned favourably relative to international peers, significant methodological headroom remains to improve its utility within the indicator-based paradigm.

A first improvement is to state more clearly what kind of harm the screening score is intended to approximate. In the UK's current framework, the main concern is economic harm to the UK, even though the score is not expressed directly in a unit such as expected GDP loss. That basic orientation should be stated as clearly as possible. If future assessments are also asked to represent other harms, such as environmental damage or human impacts in producing countries, those should be introduced cautiously and treated separately unless government makes the relevant trade-offs explicit.

A second improvement is to define more clearly which kinds of disruption each indicator is meant to approximate. Many indicator-based methods combine proxies that implicitly refer to different hazards. Production concentration, governance conditions, reserve measures, recycling rates, import dependence, and trade shares do not all describe the same process. Some may be used as rough proxies for the likelihood of disruption. Others are closer to exposure at source, exposure of the assessed subject, buffering capacity, or susceptibility to shortage. If they are grouped together inside one or two broad dimensions without a clear causal interpretation, the resulting score becomes difficult to read as a coherent quantity.

A third improvement concerns conflation of different steps in the supply chain. The same screening dimension can mix information about extraction, refining, trade concentration, firm- or facility-level concentration, downstream dependence, and sometimes logistical bottlenecks. These are not interchangeable. They refer to different stages at which disruption can arise or propagate, and they often point to different interventions. A stronger screening tool would therefore be more explicit about what part of the chain each indicator is intended to represent, even if the final result remains coarse.

A fourth improvement concerns empirical validation. This does not require every indicator to be validated perfectly before use. It does require more transparency about the evidence behind each proxy. Several indicators that recur across the literature are used mainly by convention, even where their empirical relationship to realised disruption processes has not been established.

A fifth improvement concerns the order in which indicators are combined. Aggregation is not only a matter of weighting. It also matters whether indicators that refer to different hazards, different supply-chain stages, or different consequence types are being merged too early. If likelihood-side and consequence-side proxies are averaged before the logic of the disruption pathway has been specified, the final score can lose any clear interpretation. A stronger screening tool would therefore be more explicit about how indicators are grouped and combined, and about what the resulting score is meant to represent.

Taken together, these changes would make the screening stage easier to interpret. They would clarify what kind of harm the score is intended to approximate, which hazards and supply-chain steps its indicators refer to, and how strong the evidence is behind those indicators. However, these represent incremental improvements within the bounds of screening approaches, and do not represent a clear path towards direct, targeted policy intervention.

4.2. The Leap Forward to a Simulation-Based Approach

Transitioning to a comprehensive simulation-based framework represents a significant methodological leap, which currently remains constrained by the limitations of existing models and substantial data uncertainties.

The first step in this track would be to define hazard types clearly and estimate their likelihood as defensibly as the available evidence permits. For many natural hazards, such as floods, droughts, cyclones, and earthquakes, geospatial hazard maps already provide structured information on where events occur and how frequently. Geopolitical and social disruptions are harder because no equivalent global event record exists in ready-made form. A practical route is to build curated event datasets from open reporting sources, filter them carefully, remove duplicates, and verify them against independent references where possible. In some cases, hazard identification also needs to move beyond the producing country and consider specific facilities, corridors, ports, or maritime chokepoints. This is one reason why focused studies need a more spatially explicit view of supply-chain disruption than broad country-level screening can provide [21, 22].

The next step is to translate those disruptions into UK consequences. A natural starting point is to adapt the logic already used by the U.S. Geological Survey, which defines explicit disruption scenarios and estimates their economic effects, but to do so in a way that reflects UK conditions and the UK's position inside global supply chains [15, 18, 19]. At UK level, this points to an economy-wide consequence model calibrated to UK input-output data. For international transmission, it points to linking that model to a global multi-region framework so that third-country ripple effects can also be represented. This matters for the UK because its exposure does not arise only from direct restrictions on its own imports. It can also arise when disruptions between other regions re-route trade, raise prices, or delay deliveries into UK supply chains [21, 23]. The broader disaster-impact literature is useful here because it shows why neither a rigid no-adjustment model nor a frictionless equilibrium model is likely to describe short-run disruption well. Approaches that allow constrained adaptation provide a more credible middle ground for policy use [24, 25].

For some minerals, this second step also requires more detailed representation of downstream use than standard industry tables can provide. A mineral shortage may matter to a specific product or process rather than to an entire broad industrial sector. Focused studies can therefore justify a more granular mapping of mineral inputs to particular downstream activities, and in some cases of the price and value-added effects that follow from supply restriction [15, 18, 19].

Time also matters in this second track. Short disruptions and long disruptions do not generate the same harm. Inventories, lead times, supplier switching, recycling, substitution, and the speed with which spare capacity can be brought online can all buffer a shock for a period and then cease to do so. This changes both the expected loss and the likely value of countermeasures such as stockpiles, supplier diversification, or targeted domestic capacity [26, 27, 18].

Finally, some focused studies should go beyond country-level structure and examine particular supply chains at company, facility, or corridor level. In some cases that may involve a refinery, a co-production bottleneck, or a small number of firms. In others it may involve a port, a hinterland transport link, or a maritime chokepoint [21]. This level of detail will never be feasible across all materials. It becomes most useful after the screening process has identified a smaller set of cases where the policy stakes justify closer analysis.

As is reflected by the lack of certainty and clarity in many of the above 'steps to improvement', the simulation-based approach remains methodologically underdeveloped; for many parts of the problem, solutions are little more than hypotheses. This is the primary cause of the limited scope that existing simulation-based approaches apply.

4.3. The Phased Solution (Our Recommendation)

The long-run objective should be a simulation-based criticality framework for the UK. Relative to screening tools, this approach is better matched to the policy problem because it can define explicit disruption scenarios, trace their propagation through supply chains, and express consequences in units that can be compared with the costs of mitigation. UK work should therefore move in that direction now: by adapting the emerging simulation literature to UK conditions, widening the range of hazards considered, incorporating third-country transmission through global supply chains, and developing more detailed representations for selected high-stakes cases.

That transition will take time. Existing simulation-based methods currently remain narrow in hazard coverage, demanding in data, and incomplete in their treatment of inventories, substitution, firm-level concentration, and logistical disruption. Some components, especially disruption likelihood estimation for geopolitical and social hazards, are still methodologically unsettled. Yet policymakers will continue to require near-term assessments. The UK should therefore continue to improve its screening tools in parallel rather than wait for simulation-based methods to become fully mature.

This parallel track is not wasted effort. Several of the improvements that would make screening tools more interpretable are also prerequisites for simulation-based assessment. Both approaches require clearer definition of hazard types, better evidence on the frequency and structure of disruption events, and more disciplined treatment of how likelihood-related information is combined. Predictive modelling of disruption likelihood is the clearest point of overlap. If the UK can build defensible likelihood models for different hazard classes, those models can strengthen screening results immediately and later feed directly into simulation-based consequence analysis.

Where such likelihood estimation is not yet feasible, some simulation work will need to proceed through explicit scenarios rather than fully probability-weighted estimates, at least for those hazards. That is still analytically useful, provided the scenarios are clearly specified and their limits are stated. In the meantime, screening tools will remain necessary because they can provide broader coverage across materials and support interim policy prioritisation.

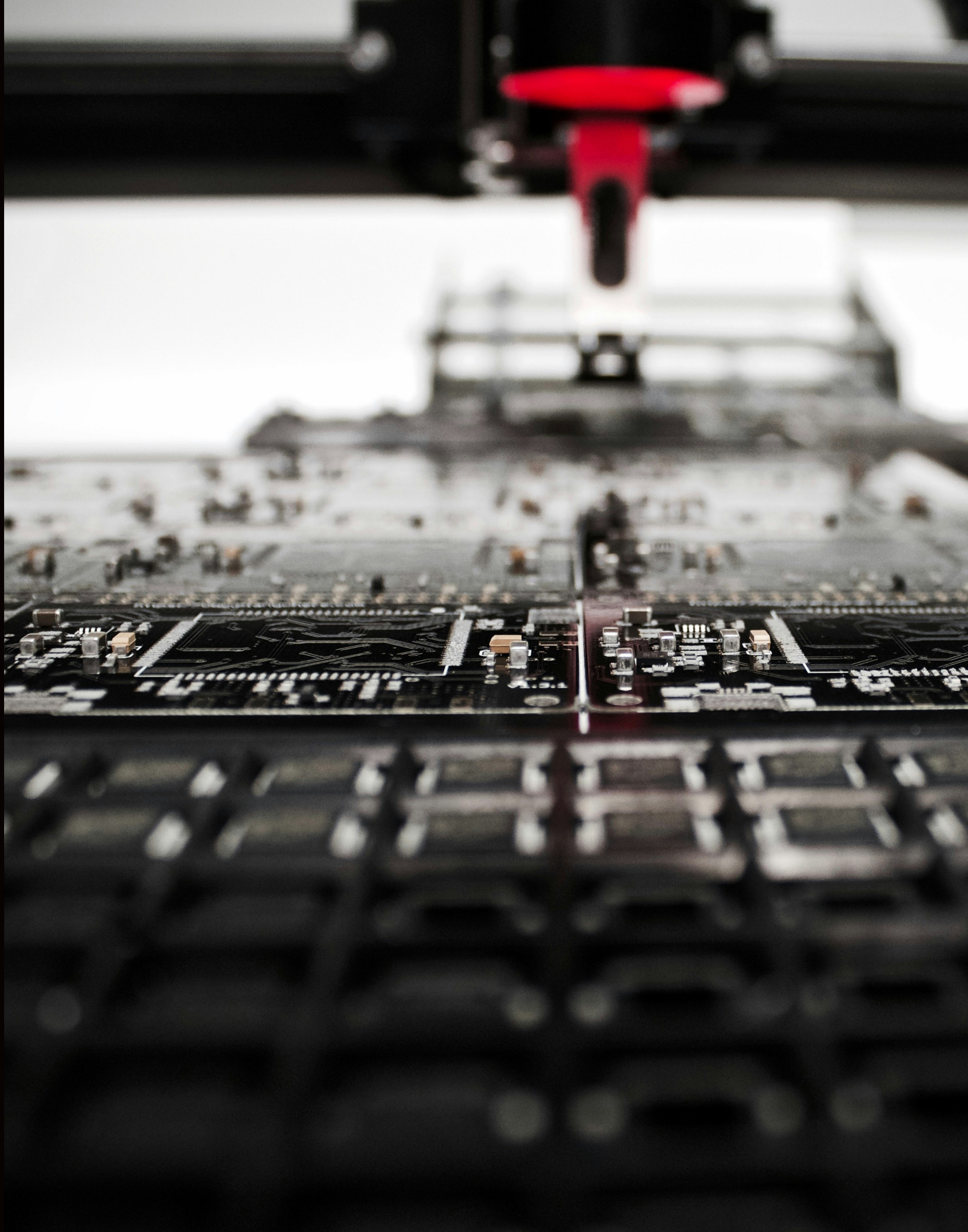
The recommended path is therefore sequential in direction but parallel in execution. The UK should treat simulation-based assessment as the destination, while improving screening methods during the transition and designing those improvements so that they also build the foundations for later simulation. This approach preserves near-term policy utility without losing sight of the more rigorous framework that future assessments should aim to achieve.

5. Call to Action

Critical material supply instability is a hazard to which the UK is especially vulnerable. This vulnerability stems from a confluence of structural factors: a lack of natural geological endowment of many scarce materials, an entrenched position as a service-based and import-dependent economy, and limited bargaining weight against geo-economic superpowers such as the United States and China.

To make the UK more resilient to critical mineral supply instability, we need to leverage our fundamental strengths. The UK remains a global leader in intellectual capital: research excellence, advanced data analytics, and regulatory innovation. It is essential to apply these strengths to this challenging geo-economic issue in which we are otherwise disadvantaged; especially when the consequences are so impactful for national and energy security.

The UK government should act on these strengths through a phased programme: improve screening tools in the near term, while building the data and modelling foundations for future simulation-based assessments tailored to the UK. That approach would provide policymakers with usable results now without losing sight of the more rigorous framework needed over time. It would base decisions on intervention on a clearer analytical basis, helping reduce risk while improving the effectiveness of state action.



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WHO WE ARE

CAMBRIDGE CRITICAL MATERIALS LAB

We believe the energy transition must be equitable and inclusive. That means mineral-rich countries and their communities should benefit fully from their resources. By co-creating information platforms, producing rigorous research, and building tools for better decision-making, we work to strengthen equity in how critical materials are used to ensure no one is left behind.

CAMBRIDGECRITICALMATERIALS.LAB

HOW WE WORK

We combine independent, interdisciplinary research with close collaboration across the Global South to ensure mineral governance is technically sound, socially just, and climate-compatible. By integrating engineering, policy, and social sciences, we create actionable insights that empower governments and communities to defend their rights, advance their interests, and navigate the complex environmental, social, and economic challenges of the energy transition.

OUR TEAM

Blending engineering, policy, and social sciences, our team finds innovative solutions to complex challenges.