## Research questions

The main research question follows from the problem statement, knowledge gaps and project objective.

***What is the supply chain resilience of Cobalt?***

**What is resilience?**

“The adaptive capability of a supply chain to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the supply chain to a robust state of operations” (Kamalahmadi & Parast, 2016).

**Data**

PANORAMA

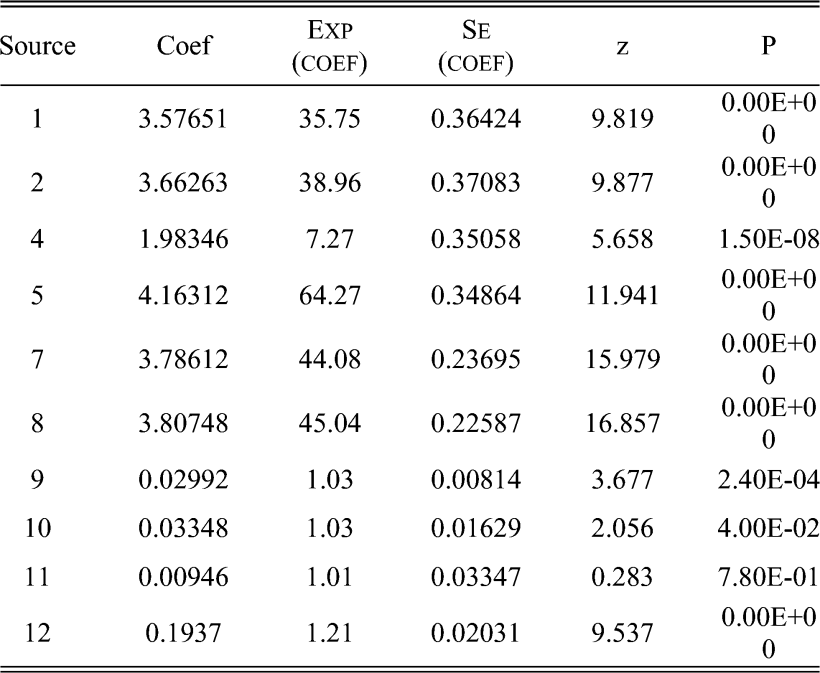
Cobalt paper excel sheet (compilation of many different sources)

# Cobalt ores and concentrates exports by country**(in 2019)**

**How do we measure resilience?**

Resilience will be measured based on the network configurations of efficiency and redundancy

1. ENA – examine redundancy and independence
   1. Calculating the alpha value – efficiency and redundancy of SC by primary + semi-refined material
   2. Calculating independence - of SC by primary + semi-refined material
   3. *Creating a cobalt network diagram – examining the links*
2. Cox PH model – survival of the system
   1. Disruption types – Based on their frequency of occurrence, SC risks that occur regularly are: supply risks, process risks, demand risks, intellectual property risks, behavioral risks, and political/social risks (Tang and Tomlin [2008](https://link-springer-com.tudelft.idm.oclc.org/article/10.1007/s10479-020-03912-1#ref-CR128));
   2. Coding using R: <http://www.sthda.com/english/wiki/cox-proportional-hazards-model>



1. Geopolitical risk calculation
   1. Cobalt mentioned in discussion section of paper: <https://onlinelibrary.wiley.com/doi/full/10.1111/jiec.12279?casa_token=S_y7J35sWVIAAAAA%3AijySj49Yk_ki6MIE3ED8-fPLl__aFSGOVXYWkBafOTuqKAP25d05FyF1SD-gg0ixigfDli6FpOqFkkQ>

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Measuring the efficiency/redundancy of the raw & semi-finished products of cobalt supply chain

To answer the main question the following sub-questions are formulated:

1. What is the current cobalt supply chain?
   1. Identifies the geographic regions involved in the supply chain
   2. Identifies what are the major companies/organizations/actors in the cobalt supply chain
   3. Literature review
2. What are the current threats to the cobalt supply chain?
   1. Identifies the internal threats to the cobalt supply chain – such as lack of material, transportation issues, labour issues, distribution issues etc.
   2. Identifies external issues that threaten the cobalt supply chain such as trade deals, geopolitical issues, economic issues, etc.
   3. Literature review
3. What is the network of final two layers of cobalt?
   1. This will be done using the ENA model and data from the PANORAMA Database
   2. Materials will be separated by product to individually analyze the resilience of each of the supply chain using a criterion scoring method
4. What are the findings from the ENA network?
   1. Identifies strengths
   2. Identifying weaknesses
5. Results and Conclusions from the diagram + context

## Research method

The proposed research project will combine theoretical knowledge from a number of different fields of study — i.e. supply chain, ecological network approach, modelling. The first two subquestions will be answered with a systemic literature review. The goal in the literature review is to understand the current supply chain structure and what the imminent threats are to the current supply chain- whether it be weather changes, war, labor shortage, etc. This will help give a well-rounded view as to the resilience of the final two supply chain layers as the understanding of the ‘full picture’ will be provided in answering the first two questions, with some threats given via the literature.

The third sub question is answered using an ecological network approach (ENA). Firstly, the data will be explored in the database to extract the relevant data. Ecological network analysis is an important tool to understand whole-system interactions (Fatha, Scharler, & Ulanowicz, 2007). This approach was chosen to give a different understanding to supply chain resilience, allowing a more holistic view. The modelling will be executed using python and GEFI for the network analysis. The fourth sub-question stems from completing the third and should be elaborated on based on understanding the real world context from the literature review don’t for RQ1 and RQ2.