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Identifying metals as potential future barriers to electric vehicle diffusion with dynamic supply risk assessment

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1. Introduction

Many countries have set aggressive targets for the widespread use of electric vehicles (EVs) [1]. As EVs become more widespread, demand for battery materials such as cobalt, lithium, nickel, and manganese is expected to increase rapidly. There have been concerns about the stability of supply of these metals, with demand exceeding supply, and countries are developing strategies to secure these metals. In addition, if the supply of these metals is disrupted, the manufacturing of EVs will be limited, and there is a risk that the EV diffusion target will not be achieved [1].

Dynamic material flow analysis (Dynamic MFA) has been used to estimate future material demand and waste. Although many studies have conducted Dynamic MFA to evaluate total material demand worldwide including EV materials and materials demand by low-carbon technologies [2], the future demand differs greatly from study to study due to the approach method and set of future scenarios: the estimated value for lithium in 2050 differs by about 10 times [2]. On the other hand, although there are studies on supply risk to evaluate the possibility of supply disruption, there are multiple indicators and the indicators used differ depending on the purpose and timescale of the study[3]. In addition, integration of multiple supply risk indicators has been attempted, but no agreement has been reached. Moreover, since technologies for infrastructure such as automobiles change over a long period, the stability of supply should not be measured based only on the current situation [4]. In this context, we focus on the issue of the supply risk of battery materials. Therefore, the purpose of this study is to dynamically evaluate the supply risk of metals that may become barriers to the spread of EVs based on the future demand for metals used as EV materials revealed by previous studies [2][5], to identify materials with supply risk, and to show the necessity of dynamically evaluating the supply risk.

2. Methodology

2.1 Target material selection and boundary setting

The metals to be evaluated were selected as materials for EVs (lithium (Li), cobalt (Co), nickel (Ni), manganese (Mn), and lanthanum (La)), and iron (Fe) and copper (Cu), which are common metals also used in automobiles, to compare the relative supply risk. The total global demand for each metal is assumed to include the spread of EVs throughout the world, and the period covered is from 2020 to 2050. Since many studies have already reported the demand and waste quantities of these metals, they were taken from previous studies of MFA research [2]. The waste amount of Mn and the demand amount of La were estimated according to the methods of previous studies[6].

2.2 Supply risk assessment

In this study, supply risk was defined as the risk of not being able to meet the demand from various social factors and characteristic factors of metallic materials such as recycling potential. Three indicators of supply risk were adopted: country concentration, depletion time (DT), and recycling rate [3]. Finally, these results were normalized to visually and relatively determine the supply risk of each metal.

Country concentration is the most commonly used indicator in supply risk studies [3] and was evaluated using the Herfindahl-Hirschman index (HHI), which is used in securities fields [3]. Since the production distribution in 2050 is future estimates, the future distribution ratio by producing country is assumed to be close to the reserves distribution ratio [4], and the production distribution in 2050 is assumed to be the reserves distribution. Both data are from the U.S. Geological Survey (USGS) [7].

DT was adopted as an indicator since it is a dynamic property that changes with geological discoveries, new technologies, and new uses, and it can evaluate the time variation of supply risk. When the value reaches zero, it indicates that the resource is exhausted and can not be supplied. Based on the method of Zhou et al [8], the DT considering time variation was calculated using equation (1).

$$\boldsymbol{Depletion\ time_{m,i}} = \sqrt{\boldsymbol{50} \times \frac{\boldsymbol{Reserves_{m,0}} - \sum_{N=1} \boldsymbol{Demand_{m,N}}}{\boldsymbol{Demand_{m,i}}}} \tag{1}$$

where $\boldsymbol{Reserves_{m,0}}$ is the amount of reserves of metal *m* in the initial year 0 (here assumed to be 2020) [7], $\boldsymbol{Demand_{m,i}}$ is the amount of metal *m* in year *N*, and $\boldsymbol{Demand_{m,N}}$ is the amount of demand for metal *m* in year *i*.

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Based on the idea that the recycling rate has a time variable determined by the amount of waste in the market and the amount of demand, recycling rate was adopted as an indicator of the availability of waste and the need for recycling and expansion of secondary production. The recycling rate here was defined as the ratio of the amount of waste with recycling potential to the amount of demand. In addition, Li and Mn are also used as additives. The amount of waste from such uses, which are economically difficult to recover due to their low concentration, was excluded, although the overall use of these materials is high.

Finally, the results were normalized to provide a relative and visual understanding of the risk for each indicator.

3. Results and Discussions

Fig.1 shows the results of normalizing the supply risk of the seven metals, with 1 being the highest risk.

In terms of country concentration, the relative risks of Co, Fe, and Cu do not change significantly until 2050, while those of Ni and Mn increase (**Fig.1** (a)).

The DT results show that all metals except Li and La are at high risk in 2020. However, by 2050, the cumulative demand for Cu, Co, and Ni exceeds their reserves (risk of 1), and the other metals are around 40 years, resulting in a bipolar situation (**Fig.1** (b)).

In terms of recycling rate, the results for 2020 and 2050 are similar except for Co (**Fig.1** (c)). This is because the amount of Co that can be recycled is larger than that of other metals.

These results indicate that common metals such as Cu, along with battery materials, are also potential supply disruptions. For example, the mineable life of Cu in 2017 was reported to be 40 years [9], which is shorter than that because the demand for Cu will continue to increase in the future. In particular, the results in **Fig.1** (a) and (b) show that Ni and Co are relatively high risks. To reduce these risks, it is necessary to reduce the amount used and introduce recycling. Furthermore, the supply risk was found to change with time, so it is necessary to evaluate the supply risk by considering the change in future demand.

It is also necessary to conduct an uncertainty analysis.

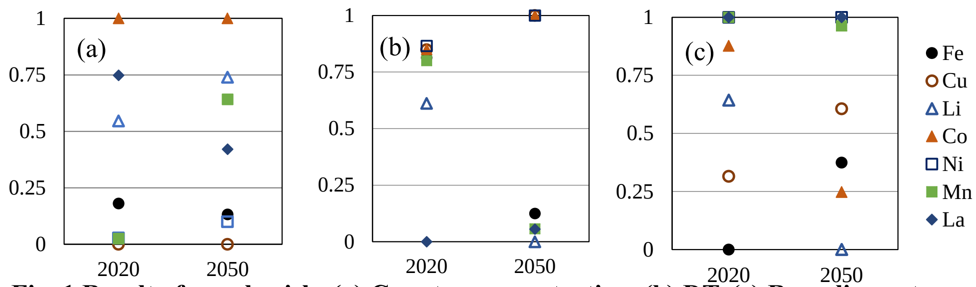

Fig. 1 Result of supply risk: (a) Country concentration, (b) DT, (c) Recycling rate

4. Conclusions

In this study, we evaluated the relative supply risk of seven metals based on previous studies that estimated future demand. As a result, not only battery materials but also common metals (Cu) were found to be at high risk, and the supply risk changed with time. The risk of Co and Ni was found to be particularly high. It also became clear that the supply risk needs to consider future changes in demand. On the other hand, it should be noted that economic growth and the new technologies may cause changes in usage in the future, which may affect the stability of supply.

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