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Future of Raw Materials Logistics

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Abstract

The world population has always been on the rise and currently stands at 7.5 billion people. [1] As the world's population grows, so do the resources needed to ensure general prosperity. The basis of all products is the provision of sufficient raw materials [2], but various raw materials are only available in limited quantities. This limitation forces us to use them in a sustainable and efficient way, which poses new challenges for the industry. Due to the growing demands, the supply chain is in a constant state of change and in the coming years there will (have to) be a rethink due to the changing conditions.

- What could the raw materials logistics of the future look like?
- What problems are facing raw materials logistics chains and how should these challenges be dealt with?

The aim of this article is to create reliable scenarios for the development of raw material logistics chains based on a comprehensive literature analysis. As a result, three scenarios are created for development based on the scenario analysis and recommendations for action for the supply chain are derived from them.

Keywords: raw materials; supply chain management; logistics; future scenario

1. Introduction and Objective

The increasing shortage of raw materials poses particular challenges for raw materials logistics [3]. For example, there is an increasing growth potential of paying attention to raw material logistics processes to optimize raw material logistics [4]. For this reason, the focus of this article is to show the current developments in raw material

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logistics, to work out possible developments in raw material logistics on the basis of a SWOT analysis and thus to present future action potentials for companies and political decision makers. The broad spectrum of developments within raw material logistics with regard to trends in the areas of politics, society, technology and processes is mapped and in the course of this a SWOT analysis is created and thus recommendations for action are made. First, the article examines different methods of predicting the future. Furthermore, trends in raw material logistics are worked out on the basis of a comprehensive literature analysis. For this purpose, a total of 2,900 literature references (BEFO, IEEE, SAE Mobilus, Scopus, OPAC databases) were examined. At first, an automated cleaning of multiple entries was performed. Then it was checked whether the titles correspond to the content of the topic. As next step, the abstracts were checked for their content reference. A total of 40 articles were identified and procured, the results of which were used to identify influencing factors.

2. Future Research

Futures research is a wide-ranging field and offers various methods for developing a statement about the future. However, it must be assumed that the future will never be predictable and therefore cannot be predicted. The main goal of a prediction is therefore not to describe what will be, but rather what may happen in the future. It is therefore a matter of describing several possible events. They are intended to support companies in their strategic orientation. There are various methods and approaches for determining what will happen in the future. According to Goepfert [5], the future research methods are divided as follows (Fig. 1)

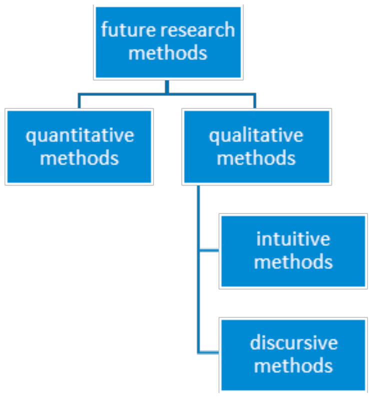

Fig 1: Classification of future research methods [5]

Quantitative methods include trend extrapolation and econometric models.

Trend extrapolation (time series and regression approaches)

With this method, past values are projected to future situations. A set of observed values is observed at equal intervals and projected to future points in time through analysis.

Economic models

Mathematical-static methods are used to test economic theory models and hypotheses for their reality content. An example is the input-output calculation, in which the interdependencies within an economy are presented in detail.

Quantitative methods have the problem that they are based on inadequate data and create a trustworthy picture of numbers and curves based on subjective evaluations without allowing for a reflected assessment. This gives the impression of absolute objectivity and accuracy. [6]

The Qualitative Methods are again divided into Intuitive Methods and Discursive Methods. Here some Intuitive Methods shall be mentioned to clarify the underlying principle.

Intuitive Methods:

- Delphi technique,
- Brainstorming,
- Intuitive confrontation,
- Normative procedure,
- Scenario technique,
- Historical analogy,
- Morphological procedures,
- Technology Impact Assessments,
- Future Workshop,
- Future seminar.

(Cp. [5], [6], [7])

3. Scenario Technique

The term scenario means the description of a future situation and how to get there [8]. The scenario method is a planning technique in which at least two or more different, yet consistent scenarios are developed and the results are used to draw conclusions for the company, an area or a research environment. The prediction of scenarios is an instrument of the prospective thinking, which opens the possibility of thinking in middle to long-term periods to arrange strategies better and safer. [7]

In order to create a scenario, it is of great importance to create framework guidelines (Table 1) for the investigation environment, as the scope is too extensive for a holistic and complete consideration of the object of investigation and its influences [9]. This work is limited to the three raw materials hard coal, aluminum and rare earths. All three have different properties with regard to transport, mining, use and availability. In this article, the focus is on the supply chain alignment of the individual type representatives. A consideration at the operational level is not included or is only dealt with in some rudimentary form. In addition, it is intended to show possibilities how the alignment of the supply chain strategy can be implemented. In contrast to the creation of future scenarios which are created within the company, no strategic planning for a specific case / company is carried out here, but for the entire value-added process of raw material logistics. The period under consideration is limited to 2040, since a later time limit would increase the uncertainties. The results of this analysis are to serve as recommendations for action in the logistical considerations.

Table 1. Definition of the investigation environment.

Subject of investigation	value chain of the three type representatives' hard coal, aluminum and rare earths, from mining to final processing
Time horizon	2040
Objective	To develop recommendations for action to align the supply chain on the basis of the scenarios created

As raw material logistics is a very complex issue, the following limitations were made in summary:

- Political, social and cultural backgrounds of individual countries are not considered further due to the high complexity,
- operational methods within the value chain are only dealt with in rudimentary form, as the focus is on the strategic alignment of the supply chain,
- Descriptors are presented on a qualitative basis, as quantitative statements would limit the scope for action [10].

In the following, the factors influencing the logistics system are considered. These were developed with the help of a comprehensive literature search (see chapter 1). The top-down principle was applied, which means that the environments were first created and then individual factors were designed.
The following environments are relevant in the case to be worked on here: Demography, technology, environment, infrastructure, consumer behaviour, legislation, raw material costs and the market. (Table 2)

Table 2. Considered Environment.

Demography	▪ World Population
Technology	▪ Industry 4.0 ▪ Extraction and processing of raw materials ▪ Drive Technology ▪ Recycling ▪ 3D printing process ▪ Block chain ▪ Autonomous transport chains
Environment	▪ Climatic conditions ▪ Worldwide hard coal reserves ▪ Worldwide reserves of bauxite ▪ Worldwide rare earth reserves
Infrastructure	▪ New Silk Road ▪ Northeast Passage
Consumer behavior	▪ Sustainability ▪ Individualization ▪ Product life cycles
Legislation	▪ Environmental legislation ▪ Coal exit
Raw material costs	▪ Raw material costs Prices crude oil ▪ Raw material prices bauxite ▪ Raw material prices hard coal ▪ Raw material prices Rare earths
Market	▪ Decentralization of production ▪ Rare earths demand

In order to find out how strongly individual environmental factors affect other areas, a network analysis, the so-called cross-impact analysis, is used and the results are then transferred to a system grid. In this case, a matrix was created during the cross-linking analysis and used to examine which forces influence the respective other system forces. An evaluation scale from 0 to 3 was used. 0 does not represent an influence of the respective factor on the other. 3 describes a very strong influence on the other system forces. The range of values has been deliberately chosen to be very small, as it often turns out during the development of the cross-linking analysis that larger ranges of numbers lead to an unclear statement of the results. The reason for this is that these are qualitative rather than quantitative elements. This would make it impossible to make a clear statement about active and passive system forces. [11]

4. Scenario Definition

Best case scenario

In this case, the best-case scenario represents a technology-optimistic path. In addition, the supply of raw materials appears to be secured and the population is demanding sustainable products.

Worst case scenario

The second extreme scenario represents the exact opposite of the first scenario. Technological progress is taking only small steps and supplying rare earths to industry outside China poses a problem for logistics.

Trend Scenario

In contrast to the two extreme scenarios, the trend scenario is located within the funnel shown and therefore describes what the future may look like if there is a balance between the respective characteristics.

Comparison of the scenarios

In all three scenarios (Table 3,4,5), strong changes for raw materials logistics in different areas were found. The scenarios differ mainly in the technological area as well as in the supply and price of the treated raw materials. Common features were the increasing world population, new trade routes and legal decisions. This resulted in the best-case scenario on the one hand and the worst-case scenario on the other, which differ greatly in terms of new challenges and opportunities. The trend scenario describes a middle course of both extreme scenarios and thus also offers new opportunities and challenges.

Hard coal

Compared to the other raw materials treated, hard coal has the difficulty of meeting a decreasing demand due to the high CO_2 emissions during the production of electric power and the resulting critical consideration by politicians and the population. This bears the danger that in the long run a complete substitution of hard coal in the energy sector may occur. However, there are opportunities in the sense that, from the current point of view, demand in the Asian region will continue to rise, as economic growth there does not allow for an early exit due to the strong demand for electricity. This provides the industry with a window of opportunity to develop new areas of application for hard coal.

Aluminum

The high recycling rate creates a second material cycle, which makes it possible to High savings potential in terms of transport distance and associated transport costs to achieve. In addition, the production of secondary aluminum is far more efficient than of primary aluminum. There is further potential for savings. At the same time this also, that there is a reduced demand on the side of primary aluminum is.

Rare earths

As a result of digitization, there will be a strong demand for rare earths. However, this demand can be secured due to the newly won reserves become. As a further benefit of the new mining sources, transport routes and associated costs and time can be saved. Through the extended supply, it comes from a transformation of rare earths as a strategic raw material into a secure supply raw material. This leads to a stability of the price.

Table 3. SWOT-Analysis Best-Case-Scenario.

Strengths	**Weaknesses**
General	**General**
- Technological progress opens up new possibilities	- Site selection Depending on mines,
- Low transport costs through technical solutions	
Hard coal	**Hard coal**
- Demand is secured	- Field of application refers mainly to power supply
Aluminum	**Aluminum**
- Supply covered by reserves	- Production of primary aluminum still more costly than that of secondary aluminum
- Recycling allows second material cycle	
- High energy saving potential in the production of secondary aluminum	
Rare earths	**Rare earths**
- Secure supply by tapping new reserves	- long transport distances despite new mining sources
- New mining sources shorten transport routes	- Opportunities

Opportunities	**Threads**
General	**General**
- New drive technology can bring enormous cost savings	- Consumers expect sustainable products
- Industry 4.0 can have a positive impact on efficiency	- Technological progress requires rapid action
- Decentralized production can shorten delivery routes	- Low inventories increase the risk of not being able to meet delivery deadlines
Hard coal	- Mass Customization and decentralization mean increased complexity in all areas
- Time window due to currently high demand in the Asian region	- Loss of jobs due to industry 4.0
Aluminum	**Hard Coal**
- Cost savings through shorter distances	- Reduction in demand due to coal phase-out
Rare earths	- Complete substitution of the raw material in power generation
- Change from a strategic raw material to a secure supply of raw material	**Aluminum**
- Independence from China	- High degree of recycling reduces demand for primary aluminum
- Price stability	**Rare earths**
	- High demand due to digitization

Table 4. SWOT-Analysis Worst-Case-Scenario.

Strengths	Weaknesses
General	**General**
- Low investment costs in the technical area due to conversion	- Lack of innovation restricts logistics more than ever
Hard coal	**Aluminum**
- Demand remains steadily rising due to lack of technical innovations in the field of energy production	- High costs due to primary aluminum production
Aluminum	**Rare earths**
- Supply remains secure	- Demand can only be covered barely or not at all
Rare earths	- Dependence on China
- Demand does not rise as strongly due to lack of innovation	

Opportunities	Threads
General	**General**
- Optimization of internal processes can secure market dominance	- High transport costs due to a lack of technical innovations in the field of means of transport
- Use of new infrastructure possible	**Aluminum**
Aluminum	- High transport costs due to errors Meeting demand with secondary aluminum
- Hard coal will continue to play a major role	**Hard coal**
Hard coal	- Supply cannot be covered
- Focus on clean technology for hard coal combustion	- View bad in population
Rare earths	**Rare earths**
- Lack of innovation means reduced consumption and thus alleviates scarcity	- Scarcity increases prices enormously

Table 5. SWOT-Analysis Trend-Scenario.

Strengths	Weaknesses
General	**General**
- New possibilities vs. old familiar	- Logistics of small steps
Hard coal	**Hard coal**
- Continued demand in emerging markets	- Reputation among the population remains poor
Aluminum	**Aluminum**
- Reliable supply due to second recycling cycle	- Primary aluminum production still very energy-intensive
Rare earths	**Rare earths**
- Slow technical progress does not lead to sudden bottlenecks	- Still no supply in abundance
Opportunities	**Threads**
General	**General**
- Organic growth possible (evolution instead of revolution)	- No extremes allow no feasts to be omitted
- No extreme characteristics thereby not so strong restrictions	- No clear preference of customers (price/sustainability)
Hard coal	**Hard coal**

- New technologies continue to be researched and can enhance reputation **Aluminum** - Compensation from primary and secondary aluminum **Rare earths** - No rapid growth in demand due to organic growth	- Slow decrease in consumption **Rare earths** - Rare earths continue to be quite limited, are therefore objects of speculation

5. Development of action measures

This phase should serve to develop a secured strategy. Since the best-case scenario promises a promising future, the focus of raw materials logistics should be based on actively influencing events in the best case. General recommendations for action are now developed for the active and ambivalent elements of environment, consumers and technology. In addition, an assessment of disruptive events is given.

Environment

The environment is the most important factor, and should therefore be considered first. The element environment included the finding of new reserves of each raw material. A secure supply of raw materials is the basic building block for ensuring general prosperity. For this reason, the focus should be on finding new reserves, especially with regard to rare earths, and thus securing the supply.

Consumers

Maximizing the end customer benefit should be the top priority when designing the supply chain. As the scenarios showed, different preferences can significantly change the alignment recommendations. For this reason, it is very important to identify early on which market is being targeted for which goods.

Technology

The ambivalent element of technology is another major driver in raw materials logistics. The demand for rare earths for the best-case scenario has been found to increase with the implementation of Industry 4.0. Since it cannot be assumed that the development of new production sites can be ensured at the same time, an efficient handling of them is therefore of great importance. Further investment should be made in the development of substitute raw materials.

Protection against disturbing events

As a result of the trend breaks, it is not possible to avoid maintaining safety stocks in order to maintain production flows. At the same time, the increasing complexity of the supply chain, which will affect logistics in the coming years, makes it very fragile. Despite all the measures taken with regard to supply security, a Pure Just-in-Time (JIT) delivery of raw materials cannot take place, as raw material suppliers, as initial suppliers, are the basic building blocks for the rest of the value chain. As a result of the nevertheless long transport routes with low transport speeds, it is only possible to react to sudden breaks in trends and thus also to changes in demand and supply with a very significant time delay for the supply chain. In addition, price fluctuations on the raw material markets are a reason for stockpiling raw materials, since they are stored when the price is low and the stock is reduced when the price rises [12]. By increasing the recycling rate for rare earths and aluminum, shorter transport distances and the associated transport times would make it possible to avoid the risk of supply shortages and minimize safety stocks, regardless of which scenario occurs.

6. Summary

The three scenarios created are intended to provide an insight into the future of raw materials logistics. There can be no hundred percent confirmation that a scenario will occur. Nevertheless, a basic strategy can be derived from the various action strategies (Table 6). A specific strategy can ultimately only be implemented by the respective companies, and depends on which scenario occurs. It is important to keep an eye on current developments and to react to changes as quickly as possible. Furthermore, the development into new technology should be encouraged in order to react to the increasing demand. In principle, technological progress in all areas is the key to successful raw materials logistics. Even if the supply of all raw materials seems to be secured in the best-case scenario, efficient handling is still important to survive in the price competition on the market. The developed measures for action should provide a framework for orientation.

The key factors for the best-case-scenario are industry 4.0, a secure supply of raw materials and a sustainable consumer orientation. Hard coal loses its importance completely in this scenario and therefore does not require a strategic Alignment. For the best-case scenario, a strategic orientation according to the Sustainable Supply Chain. This describes a supply chain that is as sustainable as possible, which is defined by the three aspects of sustainability.

In contrast to the best-case-scenario, the raw materials logistics in the worst-case-scenario are not new opportunities, but rather with new risks and challenges.

Due to the slow progress of technical innovations there are hardly any opportunities to develop and implement new innovative concepts. In contrast to the first scenario, the logistics service providers will focus on cost-optimized logistics. Transportation and raw material costs make up a considerable part of the total costs of a product, whereas customers prefer a low-cost product.

Due to the lack of development of new reserves and increasing demand as a result of population growth, supply risks can arise, especially in the rare earths sector arise.

In terms of strategic orientation, the trend-scenario falls between the two extreme scenarios. Logistics is developing successively. Therefore, this scenario does not offer any clear indications of the orientation of a suitable form of supply chain, as in the previous scenarios.

Table 6. Summary Alignment of the supply chain for respective type representatives.

	Best-Case-Scenario	**Trend-Scenario**	**Worst-Case-Scenario**
Hard coal	---	Lean Supply Chain	Lean Supply Chain
Aluminum	Sustainable Supply Chain	Sustainable/Lean Supply Chain	Lean Supply Chain
Rare earths	Sustainable Supply Chain	Sustainable/Lean Supply Chain	Supply Chain Risk Management

This work does not point out the arrival of a certain future, but rather serves as a sensitization and guide for raw materials logistics. With the established investigation framework and the limitations, a self-contained model of different scenarios could be created. This model serves as an orientation for logistics and shows where it can develop in the future. It is clear that logistics, and in particular raw materials logistics, must continue to develop and be adapted to new situations.

Finally, it should be mentioned that the path to successful raw materials logistics can and must be influenced by companies themselves from the current point of view. Investments in new technologies must be made in order to be able to meet the coming challenges and to actively navigate towards the "best-case future".

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