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Analyzing Supply Risks And Product Characteristics – A Systematic Literature Review

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Abstract

The environment in which companies operate is increasingly volatile and complex. This results in an increased exposure to disruptions. Past disruptions have especially affected procurement. Thus, companies need to prepare for disruptions. The preparedness for disruptions in the context of procurement is significantly influenced by the design of the procurement strategy. However, a high number of purchased articles and a variety of influencing factors lead to high complexity in procurement. The systematic design of the procurement strategy should therefore take into account the criticality of the purchased articles. This enables to focus on the purchased articles that have a high impact on the disruption preparedness. Existing approaches regarding the design of the procurement strategy in uncertain environments either lack practical applicability and objective evaluation or focus on the criticality of raw materials rather than of purchased articles. Therefore, a data-based approach for the systematic design of the procurement strategy in the context of the Internet of Production has been proposed. One central aspect of this approach is the identification of success-critical purchased articles. Thus, this paper proposes a framework for characterizing purchased articles regarding supply risks by combining two systematic analyses. First, a systematic literature review is performed to answer the question of what factors can be used to describe the supply risks of purchased articles. The results are analyzed regarding sources and impacts of risks and thus contribute to a structured characterization of supply risks. Second, existing criticality assessment approaches for raw materials are analyzed to identify categories and indicators that describe purchased articles. The results of both reviews provide the basis for linking product characteristics with supply risks and assessing product criticality which will be integrated into an app prototype.

Keywords

Disruptions; Supply Risks; Procurement Strategy; Product Characteristics; Internet of Production

1. Introduction

Past disruptions like the COVID-19 pandemic, the blockade of the Suez Canal or the flood in North-Rhine Westphalia have posed various challenges in supply chains and thus have demonstrated the need to prepare for disruptions. As past disruptions have demonstrated, the impact on the procurement side has been especially critical [1,2]. Procurement is responsible for organizing and ensuring the supply of external material and parts that are required for internal processes [1]. Preparing for disruptions should focus both on reducing the effect a disruption has on a company's performance as well as on enabling fast recovery after being disturbed. The preparedness for disruptions is significantly influenced by actions and strategic choices taken prior to a disruption [3]. For the area of procurement, the level of disruption preparedness is thus influenced by the design of the procurement strategy [1]. The procurement strategy determines the fundamental orientation and design of the supply process within the company and deals for example with

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the number of suppliers or the type of purchased objects [4]. A high level of complexity in procurement and a multitude of purchased products with different characteristics and various options for specifically shaping the procurement strategy contribute to the fact that one important prerequisite for increasing preparedness is having transparency of the current procurement situation and the purchased articles [5]. To handle the complexity, the systematic design of the procurement strategy with regards to disruptions should on one side take into account different data sources and on the other side consider the criticality of purchased articles. By taking into account the criticality of purchased articles, a focus can be set on articles with a high impact on preparedness. As part of the research project Cluster of Excellence "Internet of Production", existing approaches for developing procurement strategies and identifying critical purchased articles have been analyzed and it has been concluded that they either focus on raw materials or lack practical applicability and objective evaluation. Therefore, a framework for a data-based design of the procurement strategy in the context of the Internet of Production (IoP) has been proposed. [6]

This paper contributes to the framework and the criticality evaluation by systematically analyzing purchased articles regarding supply risks. On one hand, the paper aims at structuring supply risks by analyzing which aspects of supply risks are frequently mentioned in the literature and structuring them into distinct categories. On the other hand, the paper builds on existing work in the area of raw material criticality assessment to identify and structure indicators that characterize purchased articles. These sets of supply risk factors and purchased article characteristics are needed to link purchased articles to supply risks and assess their criticality. The systematic analysis thus provides the foundation for identifying relevant supply risks aspects based on different purchased article characteristics.

The remainder of this paper is organized as follows. Section 2 reviews the literature regarding supply risks and characterization of purchased articles. Section 3 presents the approach and the results of the systematic analyses. Section 4 summarizes the results and gives an outlook on the use of the results for building an app prototype.

2. State of the art

This section summarizes existing approaches to structure supply risks and to characterize purchased articles.

2.1 Supply risks

According to IVANOV AND SOKOLOV risks arise from uncertainty which is a general property of a system environment [7]. This understanding also underlies the definition by ROMEIKE. According to ROMEIKE, risks are possibilities to deviate from planned target values that result from the unpredictability of the future. [5] In the context of risks, this deviation is usually negative, while positive deviations are described as chances [8]. In the context of procurement, **supply risks** refer to "the uncertainty and severity of the events and consequences of any activity that adversely affects the inbound supply performance in terms of its target values" [2]. Supply risks affect the availability and quality of products that a company requires for its further value creation [9].

To analyze the current state regarding supply risks, general frameworks for structuring risks in supply chains are summarized first as they influence what risk factors are considered. In the literature, risks are categorized according to different criteria. SANCHIS AND POLER propose a general framework for disruption elements: A disruption is composed of a *source* that originates the disruption, a *disruptive event* that is the concrete incident that causes the negative effects and a *consequence* that is the impact of the disruptive event. [10]

Against this background, **cause-related categorizations** focus on different sources from which risks can occur. On a high level of abstraction, sources of risks in the context of supply chains can either be internal or external for the considered company or supply chain. [8] A common framework has been proposed by

MASON-JONES AND TOWILL which has been referred to by different authors [e. g. 11,8]. External risks are referred to as environmental risks. Internal risks can be further divided into company and supply chain internal risks. Supply chain internal risks include supply and demand risks while company internal risks are divided into process and control risks. SANCHIS AND POLER introduced a framework for origins of disruptions which summarizes and structures origins on different levels. On the first level, they distinguish between 11 origins: customers, distribution, economic/financial, energetic, environment, inventory, legislation, production, social, supply and technology. These are further divided into 59 sub-origins. [12]

Effect-related categorizations are oriented toward the consequences that result from the occurrence of risks. While operative risks refer to inherent fluctuations, disruptive risks are events that have a massive impact on the system. [8] SHEFFI ET AL. describe disruption in supply, disruption in transportation, disruption at facilities, freight breaches, disruption in communications and disruption in demand as possible failure modes within a supply chain [13]. CARVALHO identified four supply chain failures from the view of a single company: material shortage, capacity shortage, finished product completed but not delivered and scrap/rework [14]. With a focus on supply risks, VON CUBE ET AL. propose deviations from the expected quality of delivered parts, deviations from the scheduled date of delivery of ordered lots, deviations from the planned quantity of delivered goods, and deviations from the planned prices of procured goods as possible consequences of supply disruptions [15]. SUCKY distinguishes supply risks in quality, quantity, timing, cost and transport risks where deviations can occur [9].

Additionally, there are literature reviews that summarize different risks factors that affect several of the above-mentioned categories. One example is the review presented by HO ET AL. who identified various risks factors in the context of supply chains. These factors are classified into macro risks, demand risks, manufacturing risks, supply risks and infrastructure risks (information, transportation and financial risks). [16] HUNDNURKAR ET AL. propose a supply chain risk classification scheme that distinguishes between risk sources and risks. The classification uses product characteristics, supply chain management processes, supply chain infrastructure, external environment and human resources as categories. [17] HOFFMANN AND ROLAND differentiate supply risks into environmental and behavioral risks. The behavioral risks are further divided into financial, operative, and strategic risks. For each category, they summarize relevant risks factors. [18] WIEDENMANN AND GRÖßLER focus on the identification and categorization of relevant supply risks in manufacturing supply networks. They use a mixed-method approach that combines a structured literature review and interviews. The proposed framework contains six risk dimensions (quality, delivery, collaboration, economic, ambience and compliance) which refer to the outcomes of risks and 27 supply risks factors that refer to the sources of risks. [2]

This analysis demonstrates that the literature in terms of supply chain and supply risks is complex due to the use of different terminologies (e. g. risks, disruptions, disturbances, vulnerability) and various levels of consideration. Moreover, a vast amount of categorization approaches exists that each focus on different aspects when defining main and subcategories. The approaches often do not differentiate between sources of risks, disturbance events and consequences which increases the complexity and complicates structured analysis. Additionally, only a few approaches explicitly focus on supply risk categorization and specification. Thus, a structured analysis of supply risks is needed as a basis for a systematic design of procurement strategies.

2.2 Characterization of purchased articles

As described in a previous publication in the context of this research project, portfolio methods are often used to cluster purchased articles and derive procurement strategies. These approaches contain different indicators to characterize purchased articles regarding their supply risks. They typically divide the indicators considered into an external and an internal dimension. A limitation of portfolio methods is the lack of objectivity in the evaluation of the indicators used. A data-based evaluation is often missing. [6]

Additionally, these approaches mostly do not categorize the indicators. Due to a lack of criticality assessments for purchased articles, raw material criticality assessments were analyzed. It was found, that existing assessment approaches focus on different risks and indicators as well as on different aggregation levels [19]. Selecting the right indicators thus poses a challenge. [6] As stated before, the extent to which the identified indicators are applicable for the assessment of purchased articles other than raw material needs to be examined. These approaches thus serve as an input for the structuring of the purchased article characteristics in the next section.

3. Framework for analyzing supply risks

The proposed framework is part of the approach for the data-based design of procurement strategies in the IoP that was introduced by the authors in previous work [6]. In this approach, action research and the CRISP-DM model are combined. By going through different action research cycles, the approach aims at ensuring the practical applicability and fast implementation of the results in companies. This paper contributes to the first action research cycle, which aims at characterizing purchased articles in the context of supply risks. It lies the foundation for the second cycle which concentrates on implementing a calculation logic that enables the identification of success-critical purchased articles. This paper focuses on characterizing supply risks and purchased articles. The systematic analysis of both areas results in two factor catalogues and is the foundation for the structured analysis of interdependencies between the developed catalogues.

3.1 Structuring of supply risks factors

In this section, the results for structuring supply risks factors are presented. The results are based on a systematic literature review. This research method is chosen since systematic literature reviews offer the possibility to integrate different findings and perspectives and create an overview of already existing empirical evidence. By using a systematic approach for the literature analysis reliable findings and conclusions can be generated while bias can be minimized. [20] Systematic literature reviews are thus replicable and transparent [21]. This research uses the five-step approach for conducting systematic literature reviews in management and organization studies which has been proposed by DENYER AND TRANFIELD. The systematic analysis starts by formulating a research question (*Step 1*) which is followed by locating the studies (*Step 2*). Locating the studies includes the selection of databases and search algorithms. This step is followed by studying and evaluating the studies (*Step 3*). To do so, criteria for inclusion and exclusion of studies need to be defined. These selection criteria must be recorded to meet the requirement of transparency. After studies have been selected, the analysis and synthesis take place (*Step 4*). While the analysis focuses on identifying the individual and constituent parts, the synthesis aims at finding associations between the identified parts. Synthesis thus goes beyond pure description and aims to create knowledge through combining different studies. The final step is the reporting and use of the results (*Step 5*). [22]

Based on the underlying approach and the state of the art regarding supply risks, this literature review aims at answering the question "*What factors can be used to describe the supply risk of purchased products?*". The results of the research contribute to the structuring of different supply risk dimensions and corresponding negative effects on manufacturing companies. In this work, supply risk factors are understood as potential sources of supply disruptions that can cause different kinds of impacts.

To identify relevant studies and cover a range of different types of information, various keywords were identified and subsequently a range of search strings was developed. Several keywords for the context of procurement *(supply, upstream, supplier, procurement, source)* were combined with keywords related to risks (*risk, disruption, disturbance, critical, vulnerable*) to identify risks that occur within procurement. Additionally, keywords were added to address any existing frameworks and measurement approaches (*framework, assessment, evaluation, measurement, identification, classification*) as well as keywords that

focus on factors (*characteristic, feature, indicator, parameter, category*). Scopus was chosen as a search database as it covers a wide range of articles. The search was performed in September 2021 and was limited to articles written in English. Additional search conventions such as filters for subject areas (*Business, Management and Accounting*; *Decision Sciences*; *Engineering*) have been added. After this step, a total of 554 studies were found and were further examined in the third step of the process.

Titles, keywords and abstracts of the articles were read to determine their suitability for inclusion. Studies were included if they focused on supply risks and identified specific factors that detail these risks. Studies that did not use the supply of a production firm as their primary focus, such as articles describing energy procurement, agricultural procurement or healthcare procurement were excluded as the identified factors were too specific. This process retained 142 studies out of 554 studies. Afterwards, the full texts of the studies were closely examined, removing another 100 studies as they only marginally addressed risk factors in the procurement context and therefore did not have an additional value for the paper. Particular attention has been given to studies that identify risk factors in the supply context and attempt to provide a framework, resulting in a total of 42 studies to be considered for analysis and synthesis. Figure 1 summarizes the successive reduction of the relevant studies.

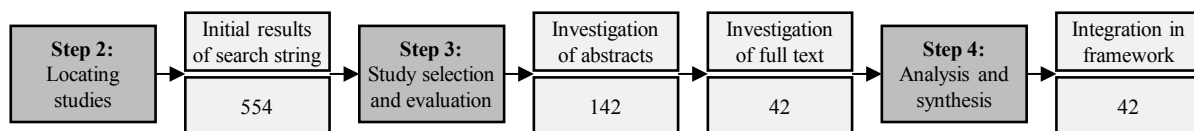| **Step 2:** Locating studies	Initial results of search string 554	**Step 3:** Study selection and evaluation	Investigation of abstracts 142	Investigation of full text 42	**Step 4:** Analysis and synthesis	Integration in framework 42

Figure 1: Progress of the systematic literature review and successive reduction of relevant studies

During the fourth step, each study was first analyzed concerning the supply risk factors it contained. The supply risks factors identified in these papers were extracted. It was striking during the following analysis that many studies chose different levels of classification and thus no clear risk assignment has been established so far. Furthermore, the wording of supply risk factors was inconsistent, resulting in a blending of risk factors, disruption events, supplier or product characteristics, and disruption consequences. The result of the analysis of the selected paper was an unstructured list of factors related to supply risks as a basis for the following compilation. Next, the wording of the factors was adapted based on their description to reflect their underlying meaning. This enabled the aggregation of factors and the removal of factors that did not specifically refer to the procurement context. Moreover, factors that did not represent risks, but characteristics or consequences were identified. These were not included in the proposed framework. Considering, existing classification schemes, the identified risk factors were grouped into five categories. The categories and risk factors es are summarized in Figure 2.

Supplier risks	**Collaboration risks**	**Transportation risks**	**Supply market risks**	**Ambience risks**
• Capacity constraints • Volume flexibility • Labor practice • Location • Technical capability • Quality requirements capability • Delivery requirements capability	• Information availability • Opportunistic behavior • Lock-in effect	• Transport capacity constraints • Handling capability • Transport failure • Transport complexity • Transport restrictions	• Input material availability • Supply sources availability • Supply market development	• Geopolitical conditions • Natural hazards • Man-made incidents • Health issues • Economic issues

Figure 2: Framework for supply risk factors

Supplier risks contain factors that arise from suppliers and relate to a specific supplier. Risk factors with regards to the production capacity of a supplier are capacity constraints [e. g. 23,24] and volume flexibility [e. g. 24,25]. They can lead to problems in the context of material availability. Besides, labor practice [e. g. 26,27] can pose supply risks, as unethical practices like child labor can result in production restrictions. The supplier location [e. g. 24,28] contributes to site-specific risks, which are closely linked to the environmental

risks discussed later on. Additionally, the capability of a supplier with regards to technical [e. g. 25,28], quality [e. g. 29,26] and delivery issues [e. g. 29,26,30] are important risks factors. Technical capability refers to the technical skills that are needed to produce the articles, while quality requirements capability relates to the processes and control to ensure the quality of products. Delivery requirements capability is the ability to deliver the requested article at the requested time.

Collaboration risks refer to the relationship with a supplier. An important risk factor mentioned by various authors is the information availability [e. g. 28,29]. Problems occur when information is delayed or the communication networks are unstable. The behavior within a collaboration poses a risk if one partner takes opportunistic actions [e. g. 26,30]. Another risk factor in this context is the lock-in effect [e. g. 31,27]. In that case, switching suppliers is difficult which hinders flexibility.

Transportation risks summarize factors that relate to the logistical aspects of procurement. Risk factors like transport capacity constraints [e. g. 32,31] and handling capability [e. g. 32,33] correspond to the factors of the category supplier risks. Capacity constraints include shortages in terms of a specific transport mode or shortages in space and containers. The factor handling capability refers to the required ability when packing, loading and transporting goods so that no damages occur. Additionally, transport failure [e. g. 29,34], transport complexity [e. g. 24,35] and transport restrictions [e. g. 24,30] are relevant risk factors in this context. Transport failure refers to the impossibility of transport execution for example due to an accident or transportation breakdown. Transport complexity is influenced for example through the number of transfer points and can increase vulnerability. Transport restrictions can occur when crossing borders are required and can impact timely delivery.

Supply market risks focus on the supply market and its development as a whole. Risk factors relate to the availability of input material [e. g. 25,2] and supply sources [e. g. 36,26]. The factor input material availability refers to the availability of raw material and the input that is required by the suppliers. The factor supply sources availability includes the existence of potential suppliers. Another risk factor is the supply market development [e. g. 36,37], which includes for example volatility in terms of the number of consumers and suppliers.

Ambient risks contain risk factors that arise from the supply environment. Following WIEDENMANN AND GRÖßLER this category is named ambient risks to avoid ambiguous interpretation [2]. This category is broader than the mere supply market risks and contains factors that cannot be influenced as such and affect various areas in the supply environment. Risk factors are geopolitical conditions [e. g. 35,34], natural hazards [e. g. 35,34], man-made incidents [e. g. 30,2] as well as health issues [e. g. 27,37] and economic issues [e. g. 35,33]. Geopolitical conditions are for example influenced by political conflicts and unrest or war but also include export or import restrictions that hinder supply activities. Natural hazards include tsunamis or earthquakes while terrorism is an example of man-made incidents. The factor health issues contains for example pandemics. Economic issues include currency fluctuations, stock market instability, global economic performance and inflation. [35]

Following VON CUBE ET AL., impacts of supply risks can be distinguished in deviations from the expected quality, the planned quantity, the scheduled date of delivery and the planned price [15]. As an additional impact, the overall availability of the procured material was added to the framework as it results in deviations regarding quantity, time and price. Each risk factor can be linked to at least one of these impacts.

3.2 Structuring of purchased article characteristics

This section presents the results regarding the structuring of purchased article characteristics. In previous research by the authors existing criticality assessment approaches for raw materials have been identified [6]. These approaches as well as studies from the systematic literature review described above are the basis for

the following analysis. The aim is to identify indicators and categories that describe purchased articles in the context of supply risks.

Previous research analyzed eight different approaches, dealing with criticality assessment approaches for raw materials [38–44,19]. For this paper, each study was re-examined, and the indicators used to describe and categorize the purchased articles were incorporated into an unstructured list. Next, it was examined which studies explicitly referred to raw materials and whether they applied to the broader category purchased articles as well. Most characteristics were applicable if they did not specifically relate to raw material extraction in terms of mining. Besides, two other sources that characterize purchased articles were considered in the analysis [45,46]. In addition to these sources, results from the systematic literature review were taken into account. During the systematic literature review, it was found that some of the identified risk factors were not related to the general context of the procurement process, but were very specific in terms of the purchased articles. With regard to the structuring of purchased article characteristics, the risks and indicators directly relating to product characteristics were not considered in the above-described framework but analyzed here. Following the above-described approach for the synthesis and analysis, the characteristics were collected in a list and their wording was adjusted to reflect the underlying meaning. This enabled the aggregation of the named characteristics. This was followed by a grouping and categorization of the characteristics of the purchased articles. The compiled indicators needed to characterize the product and at the same time can be linked to the previously listed supply risks. As can be seen in Figure 3, four categories were established. The characteristics are either not-related to suppliers (product characteristics and economical aspects) or related to suppliers (supplier characteristics and logistical aspects).

Product characteristics	Economical aspects	Supplier characteristics	Logistical aspects
• Product specialization • Product vulnerability • Hazard risk / safety specifications • Frequency of product changes • Product's lifecycle position • Demand volatility • Resource competition • Substitution possibility	• Volume purchased • Total purchasing cost • Material utilization • Material value • Strategic importance • Revenue impact • Price volatility	• Number of suppliers • Diversity of supply • Lead time • Reliability	• Import dependency • Supply distance

Figure 3: Framework for purchased articles characteristics

Product characteristics cover not only the physical characteristics of the purchased product but also relate to its specific supply market. Product specialization [e. g. 44,46] describes the uniqueness of a purchased article in terms of its level of complexity and individuality. Product vulnerability [e. g. 46] describes the susceptibility of a procured article to external influences that have a diminishing effect on its performance level. The hazard risk or safety specification of a product [e. g. 23,26] is based on its occupational requirements in terms of physical, chemical, biological or ergonomic requirements. The frequency of product changes [e. g. 23,36,46] describes the number and intensity of both technical and design changes to the purchased article. A product's lifecycle position [e. g. 45,26] is usually defined by how long it has already been on the market and whether there is a chance that it might be discontinued. One characteristic that is also frequently mentioned regarding supply risks is the volatility of the demand [e. g. 24,43,19]. Resource competition [e. g. 42,43] refers to the popularity of the article and is based on competing demand for an article that is available only in limited quantities. Substitution possibility [e. g. 42,46] describes how well the purchased article can be replaced through another article.

Economical aspects are mainly intended to describe the importance of an article for the buying company and the effects on economic targets. The purchasing volume or consumption volume [e. g. 40–42] is the quantity of a purchased article that is ordered within a certain period. Purchasing costs [e. g. 45,41] are understood to be the total costs for carrying out the procurement process, so that the importance of an article is described by its percentage of the total purchasing costs [42]. Material utilization [e. g. 45,47] describes

the extent to which a purchased article is used in finished products. The material value [45,40] refers to the financial value of the utilized material and is directly related to the purchasing cost. Strategic importance characterizes the impact of a product on the company's strategic objectives [e. g. 40,42], while revenue impact [e. g. 19,46] expresses the importance of the product to the company's income. Price volatility [e. g. 39,41] describes the tendency of a product to fluctuate in price, which is explained, for example, by changes in the market or regular changes in the price of related raw materials. The tendency of a product to develop price spikes is also considered here.

A purchased article is moreover characterized through the suppliers that deliver this article. **Supplier characteristics** thus contain characteristics that relate to the actual suppliers from which a company purchases the articles. The number of suppliers [e. g. 26,42] is the actual amount of available and capable suppliers. Despite the number of suppliers, a product is characterized through the diversity of supply [e. g. 48,19] which refers to the geological distribution of suppliers and their production or export structures. A purchased article is also characterized through the lead time needed for its delivery [e. g. 45,39,28] which is dependent on the supplier. The last characteristic that directly refers to a supplier is its reliability [e. g. 45,39]. It includes the adherence to delivery dates, quality and delivery amount aspects.

As the last category, **logistical aspects** include characteristics that refer to the transportation process which is performed when delivering the articles. These characteristics are thus influenced by the location of the suppliers. Import dependency [e. g. 40,19] indicates the extent to which an article must be imported or is available domestically. Supply distance [e. g. 41,46] refers to the transport distance between the suppliers and the location of the buying company. The supply distance influences possible modes of transportation, delivery time and transportation costs.

4. Conclusion and outlook

Risks in the context of procurement are interpreted and understood in various ways within the literature. The systematic design of the procurement strategy influences the risk exposure and thus requires knowledge about the relevant risk factors. Additionally, complexity in procurement requires focusing on articles with a high impact on disruption preparedness. Therefore, supply risks factors and purchased article characteristics have been systematically studied. Using a systematic literature analysis, a variety of sources were analyzed. Based on the results a framework for supply risk factors was proposed which contains five categories and 23 risk factors. The identified risk factors are potential sources of supply disruptions. The disruptions can result in deviations from the expected quality, the planned quantity, the scheduled date of delivery, the planned price and deviations in the overall availability of the procured material. Additionally, purchased article characteristics were analyzed. The resulting framework for purchased article characteristics includes characteristics related to and not related to suppliers and is structured in four categories with 21 characteristics. The results create transparency on the relevant aspects both in the context of supply risks and purchased article characteristics. They are thus the basis to analyze the interdependencies between article characteristics and supply risks. The supply risks for an article then result from a combination of certain purchased article characteristics. This allows the identification of critical articles. Further research is needed to identify the links between the identified factors and characteristics. In this context, interdependencies between different risk factors should be taken into account as well. Once the links have been analyzed the results will be integrated into an app prototype which enables the identification of critical purchased articles. The app prototype will use data from different business application systems to characterize purchased articles and derive statements regarding their supply risks.

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