# AN OVERVIEW OF RISK MODELING AND REPRESENTATION IN BUSINESS PROCESS MODELING LANGUAGES

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Abstract: *Business process modeling is important because it allows us to clearly and unambiguously define business processes, to identify the company's operations. It provides formal knowledge about work performance, work standardization, process analysis, and risk detection, leading to process improvement and automation possibilities. This paper focuses on the BPMN (Business Process Modeling Notation) modeling language, which aims to facilitate understanding and usability for all business users, participants, analysts, and software engineers. Before creating the model, it is crucial to determine the modeling goal, as companies encounter unforeseen events that can impact business objectives. Timely identification and assessment of risks, along with consideration of their consequences, are essential to prevent adverse effects. BPMN allows comprehensive process mapping and real-time monitoring to aid in risk identification. By integrating risk management into the process model, proactive identification and mitigation of risks can be achieved, reducing the likelihood of risk occurrence. While BPMN 2.0 lacks risk management constructs, various authors offer suggestions that will be presented in this paper.*

Key words: BPMN, risk, risk management

## 1. INTRODUCTION

Small errors in business process modeling can have significant consequences. This is because many employees may not be aware of or adequately consider all the potential risks that could lead to major consequences later in the process. Michael zur Muehlen and Michael Rosemann (2005) provide an example in their work where a typographical error in the entry of a date in payroll lists resulted in a series of problems, including unpaid salaries and unmet obligations to employees. The cause was a simple data entry error made by employees, which went unnoticed by other employees working on the same tasks. This happened despite clearly defined salary payment processes and accuracy assurance based on double signatures. No one had recognized the risk of a possible data entry error, leading to errors cascading throughout the entire business process. If the company had been aware of this risk and had managed it properly, these issues could have been avoided.

Identifying process risks, such as data entry errors, is crucial for ensuring business continuity and complying with regulatory requirements, particularly those related to data protection and financial transactions. Compliance with legal standards depends on analyzing the business processes where sensitive information is generated, accessed, or modified.

This paper addresses the importance of business risk management, emphasizing that companies need to be aware of the risks associated with their business processes. Awareness alone is insufficient; companies must develop methodologies for risk management. This can involve minimizing risks or understanding the consequences of risks that cannot be managed differently. One risk management methodology includes collaborating with other companies to reduce shared risks. The paper focuses on developing techniques for process modeling that incorporate the risks associated with the process. In the realm of business process management, risk is a factor that significantly influences process management. While there are many works in the literature on this topic, it's essential to highlight the case study of the Little Rock Music and Arts Festival by Ballou et al. (2000). This study considers risk at the business process level, but it remains at a high level of abstraction, primarily focusing on financial and general business risks while neglecting operational risks. The paper's objective is to present techniques for modeling risk inclusion in business process models, both at the overall process level and at the level of individual activities.

Reijswoud and Hommes (2000) have provided frameworks for defining business process modeling techniques. According to them, each model consists of four essential elements: notation, meaning, connection concept, and modeling concept. Modeling methods inform us about the models used for specific techniques, while working methods describe the procedures employed to build these models. There are three fundamental formats for modeling: horizontal, vertical, and cascade.

Before creating the model itself, it is crucial to determine the modeling goal. When modeling business processes, it is important to choose appropriate techniques and tools, as the modeling process is complex and involves numerous modeling languages, some of which lack detailed instructions. Process maps, which are graphical representations of business processes describing step-by-step procedures, are used for modeling. While these maps provide an overview of the process flow, they are not sufficient for a comprehensive representation. To obtain a detailed view, business process modeling tools are utilized, enabling statistical evaluation of process performance in different scenarios and facilitating design optimizations. These modeling tools also allow resources to be represented, providing insights into potential risks. Analyzing and measuring business processes are essential prerequisites for effective business process modeling. During the analysis, the flow of the process itself, elements, participants, and technological systems are examined to identify and document all processes.

## 2. RISKS AND BUSINESS PROCESS MODELING LANGUAGES

To discuss risk in the context of a process, it's essential to have a good understanding of the term "business process". Risk management is a highly complex process and presents a significant challenge for organizations in mitigating risks. The process of risk identification enables us to take appropriate mitigation measures when potential risks arise. Risk assessment involves evaluating the impact of risks and their probability of occurrence (Schechtman, 2002). Enterprise Risk Management (ERM) is a form of management that addresses uncertainties in an organization's operations. ERM aims to move away from managing individual risks in isolation and instead adopts a holistic view of risk management (Akram & Pilbeam, 2015; Mensah & Gottwald, 2016). It is important to note that many risks are interconnected, and standard risk management approaches often fail to establish the relationships and correlations between risks.

Business Process Management (BPM) combines a managerial approach with appropriate technology to enhance company performance (Benedict et al., 2013). BPM focuses on the business-oriented aspect of change management to achieve improved business processes and align them with overall business goals.

The need to incorporate risk into business process models has driven the development of risk-aware business process management (R-BPM) (Suriadi et al., 2014). The integration of BPM and ERM has resulted in R-BPM (Thabet, 2018), which aims to effectively identify, detect, and manage process-related risks (Jakoubi et al., 2010). Modeling business processes with risk awareness is a crucial task in the R-BPM life cycle, necessitating the inclusion of risk-related information in business process models.

Various languages exist for modeling business processes, including Event Driven Process Chains (EPC), UML Activity Diagrams, Business Process Model and Notation (BPMN), Petri Nets, among others. Although some of these languages cover different aspects comprehensively, none of them adequately integrate risk and business processes. Efforts are underway to incorporate risk into process models to enable a holistic evaluation of process performance. However, research and practice in risk-aware business process modeling remain limited and require further investigation.

Business process modeling is significant as it allows clear and unambiguous definition of business processes to identify company operations. It provides formalized knowledge about work performance, standardizes work, enables process analysis, facilitates risk detection, and supports process improvement and automation. In a study by Favera et al. (2020), experts expressed the desire for risk management information to be represented in business process models, viewing them as additional means of communication to guide stakeholders in their risk management activities. Experts only care about the complexity of the model, which should be taken into account when integrating risks into modeling languages.

The EPC modeling language partially supports risk modeling, allowing for the identification and linkage of risks to specific process activities within a detailed business process model [Anton 2016]. Additionally, within the same methodology as EPC modeling, it is possible to create separate formal models solely focused on risk, resembling the organizational structure model [Anton, 2016]. In the case of UML activity diagrams, direct support for risk modeling is not provided. However, as UML is not limited to activity diagrams alone, integrations have been developed between UML methodologies and corresponding standards covering information security (Fabien, 2022), as well as software solutions for risk management (Gorecki, 2021).

Business Process Modeling Notation (BPMN) was developed by the Object Management Group (OMG) as a visual representation language for processes in the IT industry. BPMN utilizes elements to construct business process models. While BPMN underwent significant changes in its 2.0 version released in 2011,

it still does not include specific elements related to risk management. The primary objective during the development of BPMN was to ensure its comprehensibility to all business users. Unlike EPC, BPMN does not incorporate graphical symbols or elements explicitly designed for risk expression within process modeling (Dalla Favera et al., 2020).
EPC (Event-driven Process Chain) is a modeling language that represents various enterprise elements and their connections to business processes. EPC shares similarities with BPMN, including functions or activities, events, and exclusive, parallel, and inclusive connectors. However, unlike BPMN, EPC addresses organizational aspects, incorporates data, and includes groups of risk elements (Favera et al., 2020).
According to Sikavica and Hernaus (2011), key characteristics of a business process include having a specific goal, an owner, a defined start and end, inputs and outputs, customers, cross-functional activities, complexity, dynamics, repetitiveness, automation potential, measurability of success, and room for improvement. Notably, each process having its owner is crucial from a risk management perspective, as the process owner is responsible for implementing measures to mitigate risks. In cases where multiple functions are involved, introducing a new role of process owner and process manager becomes necessary to maintain a balance between the process and the functional organization. In risk management, it is essential to assign a responsible person, often referred to as the risk owner, for each identified risk.
In the context of this paper, with its focus on risks, two aspects are significant. First, the close relationship between processes and goals illustrates that processes can have various goals, and these goals are supported by activities within the process. As risks are clearly linked to activities, they must also be interpreted in the context of objectives. A risk that could potentially cause a one-day delay in the entire process is relevant in a process aiming for a quick turnaround but may be less important in a process focused on ensuring high quality. Second, a process encompasses much more than a mere sequence of activities. Therefore, there are numerous other sources where risks can potentially become relevant. Risks can be associated with incoming business items, data, information technology resources, and so on.

## 3. ANALYSIS OF RISK INTEGRATION INTO MODELING LANGUAGES

The previous sections of the paper have highlighted the complex nature of processes and risks. Conceptual modeling is a well-established approach for comprehending various forms of complexity, including those related to data, processes, organizational structures, and more (Gupta and Sikes, 2001). However, traditional information system modeling techniques such as EPC, UML, Petri Nets, or IDEF do not explicitly incorporate risk-related information at this stage. We propose the use of conceptual risk modeling to ensure that risk is integrated into process management projects.
Michael zur Muehlen and Michael Rosemann (2005) suggest three interconnected types of models to effectively incorporate risk into the context of business processes. They employed the widely accepted architecture of integrated information systems (ARIS) and extensions of the embedded event-driven process chain (EPC) notation to illustrate their concepts (Scheer, 2000). Two of the three model types pertain to the structural and behavioral aspects of risks, while the third acts as an integration model that connects risks to process goals and the overall process structure.
The three proposed model types are as follows:

- Risk structure model,
- Risk target model,
- Risk state model.

In this section of the paper, we focus on the analysis of risk integration in various modeling languages, with particular emphasis on the BPMN language for business process modeling. BPMN is widely used in modeling business processes due to its comprehensive coverage of the BPM life cycle phases and its ability to construct process models (Panagacos, 2012).
Meland and Gjære (2012) conducted a study on the use of BPMN 2.0 in the security community. They highlighted the benefits of BPMN 2.0 in designing and executing complex services with dynamic behavior by incorporating threats as part of the process model. These threats can cause deviations from normal business processes. The authors provided examples of how threats can be represented using symbolic constructs and diagrams in BPMN 2.0, such as error events, escalation events, and text notes. Meland and Gjære (2012) proposed a BPMN meta-model for risk visualization, aiming to include more detailed information beyond just risk names. They acknowledged the limited support for BPMN 2.0 in existing tools but noted that BPMN 2.0 provides a wide range of constructs and diagrams suitable for threat modeling. The authors concluded that extending the notation or meta-model is unnecessary since escalation events adequately describe threats, and further additions would only create confusion among

modelers and the public. However, Anton et al. (2016) criticized this approach, pointing out that exclusively presenting risks through events disregards other aspects of the risk phenomenon.

In their scientific paper, Marcinkovski and Kuciapski (2012) aimed to enhance BPMN for risk management by utilizing error events. They noted that the textual annotations in BPMN for risk identification were not sufficiently clear and precise. To address this, they introduced risk factors that provide a comprehensive characterization of potential risks based on their type, probability, and impact on the overall business process. They emphasized that one risk factor can be associated with multiple types of risks, but at least one type of risk must be specified. Furthermore, for each identified risk, an appropriate solution should be assigned. To assess the severity of a given risk, Marcinkovski and Kuciapski (2012) assigned a score ranging from 1 to 5 for both the probability and impact factors. As is widely known, the total risk is calculated by multiplying the probability and impact values.

Bernasconi et al. (2013) aimed to enhance the clarity and effectiveness of risk modeling, particularly for analysts involved in risk identification and assessment. They employed a data object to represent risks, which modeled activities and flow controls in business processes. The authors focused on the cause-and-effect relationship between risks and their patterns, utilizing Fuzzy Cognitive Maps (FCM) for clarification. FCM served as a valuable tool for visualizing and representing the interconnections among risks, including the causal links between individual risks and their causes, as well as relationships between different risks. To further improve clarity and precision, Bernasconi et al. (2013) introduced a new element in FCM: the specification of the difficulty in detecting the causes of risk. Additionally, they employed Fuzzy Logic as a formal method to address the challenges posed by incomplete and fuzzy data, thereby providing a more robust and reliable framework for risk assessment.

Radloff et al. (2015) focused on an extension that enables an integrated representation of business processes and control tools to support the implementation of process audits within EPC. They also mentioned the potential contribution of their extension to BPMN.

Anton et al. (2016) examined risk analysis in the modeling of business processes across various modeling languages. They found that none of the proposed extensions covered all relevant aspects of risk, and these extensions were not compatible with each other. They analyzed BPM languages as well as "generic" languages not based on BPM. They emphasized the cause-and-effect chain of risks and highlighted the importance of the business owner and external actors in risk-awareness during the modeling of business processes. Similar to Bernasconi et al. (2013), they underscored the significance of understanding the impact of risks on each other, rather than focusing solely on individual risks. Anton et al. (2016) also noted the importance of time sequence, recognizing that there is often a time gap between the occurrence of the cause of a risk and its subsequent consequence. They observed that existing approaches did not fully capture all aspects of the risk phenomenon and proposed an extension to BPMN to address these limitations. In their proposed extension, they integrated risk phenomena directly into existing BPMN diagrams, which can be toggled on and off without affecting the process structure. This integration allowed for the management of risk elements without impacting the overall process structure. They introduced additional risk-specific elements represented by an octagon shape and introduced the term "risk flows" to describe the relationships between risks. The risk owner was represented using a pool line, clarifying the responsibility for managing identified risks. Through these proposed improvements to BPMN, Anton et al. (2016) aimed to overcome the identified limitations and provide a more comprehensive framework for incorporating risk analysis into business process modeling.

Cardoso et al. (2021) emphasized the importance of risk assessment for business processes and its impact on their design and control. They presented their own extension, riskBPMN, which was developed using the native extension mechanisms offered by the BPMN meta-model. This extension aimed to facilitate quantitative risk assessment and built upon relyBPMN, an existing BPMN extension designed for reliability assessment. Due to the absence of an official methodological guideline for extending the BPMN 2.0 meta-model, the authors proposed a three-step methodology inspired by the approach presented by Stroppi et al. (2011). The first step involved defining a conceptual model of the extension domain using UML, establishing basic extension concepts and understanding domain-specific elements and relationships. The second step focused on defining the BPMN extension model, describing how the riskBPMN extension integrates with the existing BPMN 2.0 meta-model using the standard BPMN extension mechanism. This step specified additional elements, attributes, and relationships that comprised the riskBPMN extension, ensuring seamless integration within the BPMN framework. The third and final step of the proposed methodology involved defining the extension of the XML schema, creating an XML schema for validating instances of the risk BPMN extension. This ensured compatibility with the existing BPMN 2.0 meta-model and proper integration into BPMN-compliant tools and systems. In quantifying risk in business processes,

risk BPMN considered both the probability of failure associated with the process and the corresponding business loss. The probability of failure represented the reliability of the process, while the impact of failure referred to the business value at different levels of the process fragments. The authors also mentioned the consideration of quantitative risk acceptance criteria for risk assessment.

## 4. CONCLUSIONS

Process management and risk management are topics that are gaining increasing popularity. However, at this stage, there are no consolidated approaches that either apply the process paradigm to the discipline of risk management or consider risks as an integral part of business processes. Our work aims to take a step toward risk-aware process and modeling techniques. We propose three interconnected types of models, as explained in the previous sections of the paper, which collectively address risk-related requirements. These model types, particularly the target risk model, state risk model, and EPC, extend the widely adopted ARIS approach to risk visualization. Consequently, they hold potential significance for organizations that have an interest or urgency to model risk within the context of their business processes. These results also hold importance for modeling tool manufacturers who are facing demands to provide conceptual risk modeling solutions.

However, it's important to note that this work has several limitations. Firstly, we are still in the early stages of exploring risk assessment and its impact on business processes. In future research, we intend to delve into the management of business risks and their effects on business processes, with a focus on evaluating the effectiveness of internal controls, an aspect that has been relatively overlooked in risk research. Our current evaluation method largely relies on descriptive arguments aimed at addressing this issue, and we are actively seeking more comprehensive solutions.

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