By-Design Approach for Business Process Compliance through AI*

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Abstract

Business Process Compliance (BPC) is essential to ensure that business processes adhere to relevant regulations, policies, and standards. Despite substantial progress in compliance rule modeling, design-time verification, and run-time monitoring, existing BPC approaches still exhibit significant limitations, leading to largely reactive rather than proactive compliance management. Integrating Artificial Intelligence (AI) into BPC offers new opportunities to address these issues, but also introduces relevant challenges, including the automated extraction and formalization of compliance requirements, and adherence to organizational, legal, ethical, and societal expectations. This research proposal will tackle these challenges through a *by-design approach to AI-enabled BPC*. The paper outlines the research gap, identifies the research questions, and presents a possible methodology and envisioned solutions for addressing them.

Keywords

Business Process Management (BPM), Artificial Intelligence (AI), Business Process Compliance (BPC), Legal Compliance, AI Ethics.

1. Introduction

In Business Process Management (BPM), business processes (BPs) must comply with constraints arising from both internal (e.g., policies and rules) and external sources (e.g., regulations and laws). Business Process Compliance (BPC) encompasses techniques that ensure BPs adhere to formal standards, particularly legal requirements [1]. As BPC bridges the legal and BP domains, it must integrate both their prescriptive and descriptive aspects [2]. Compliance requirements are typically organized hierarchically across policies, regulations, and standards, allowing compliance to be addressed at multiple levels throughout process modeling and implementation.

Despite advances in compliance rule modeling, design-time verification, and run-time monitoring [3], existing BPC approaches still present important limitations. Most frameworks focus on specific compliance-checking strategies and provide limited support for scalability and cross-domain reasoning, resulting in predominantly reactive compliance management. Since regulations continuously evolve due to legal, policy, and business changes, BPC must be managed proactively. Consequently, there is the need for intelligent tools that can dynamically adapt to regulatory changes, proactively detect design-time violations, and recommend mitigation actions.

Artificial Intelligence (AI) offers promising solutions to these issues. Techniques such as natural language processing (NLP), machine learning (ML), and explainable AI (XAI) enable a shift from static rule checking to proactive BPC management. AI-driven systems can monitor data, predict violations, and explain decisions, supporting adaptive and trustworthy BPC management through collaboration between AI and human experts [4]. While integrating AI into BPC opens new opportunities, it also poses important challenges, including the automated extraction and formalization of compliance requirements, the provision of explainable reasoning about violations through human–AI collaboration, and the alignment of AI-driven BPC management with legal, ethical, and societal requirements.

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To address these challenges, the aim of this research is to propose a *by-design approach to AI-enabled BPC* that supports proactive, transparent, and trustworthy compliance management in accordance with the requirements of the AI Act [5]. The rest of the paper clarifies the research gap, identifies the research questions, and presents a possible methodology and envisioned solutions for addressing them.

2. Research Problem

2.1. State of the Art

Business Process Compliance (BPC) fundamentally relies on legal compliance to ensure adherence to obligations and external regulations. Existing compliance-checking approaches model compliance as an alignment between legal and process events [3]. However, they operate ex-post, during monitoring and verification, and do not enable the design of compliant BP by construction.

An interdisciplinary perspective on BPC has been explored through the Artificial Intelligence Methodology (AIM), which supports AI-driven legal compliance [6]. AIM enhances BPs with AI and provides a way to model AI systems within BPs. However, it does not leverage AI to ensure compliance with the specific regulatory frameworks governing a BP, a gap this research aims to address. Moreover, AIM assesses compliance ex-post by verifying that all process traces satisfy legal requirements expressed manually in Defeasible Deontic Logic (DDL). While DDL offers an effective representation of normative rules, manually translating and maintaining large sets of regulations is not scalable. Although automated techniques such as NLP may help with complex legal reasoning [7], fully manual rule specification is likewise unsustainable, especially in complex regulatory environments.

Existing research on BPC has mainly focused on BP standardization and activity labeling [8]. In particular, studies have explored standardization strategies [9] and their complexity [10]. While BP standardization supports digital transformation initiatives such as Robotic Process Automation (RPA) [11] and process mining-based compliance monitoring [12], it largely overlooks legal constraints and the ethical implications arising from AI-driven compliance.

BPC approaches are generally classified into forward and backward compliance checking. While backward checking assesses compliance after execution, forward checking operates at design or run time. However, both rely on verifying processes against predefined compliance requirements rather than integrating regulations directly into BP design. As highlighted in [13], a formal design methodology for embedding laws and norms into BPs is still lacking. Even design-time approaches mainly measure deviations from compliance patterns, which are often difficult to derive from regulations.

To the best of our knowledge, the AI-enabled BPM vision proposed in the manifesto on AI-augmented BPM systems (ABPMS [4]) has not yet been applied to BPC within specific legal and ethical contexts. Furthermore, the social implications of AI-supported BPC remain largely unexplored, particularly regarding trust, cognitive effects, and human decision-making. While responsible AI for BPM should ensure fairness, accuracy, confidentiality, and transparency [14], its impact on users' trust and critical thinking in compliance tasks has yet to be investigated.

2.2. Research Questions

The main research question **RQ**, along with the more specific sub-questions **RQa**, **RQb** and **RQc** that guide this research, are presented below and illustrated in Fig. 1:

RQ: How can Business Process Compliance be achieved by-design through AI?

RQa): *How can AI be used to identify the relevant set of policies, regulations, and laws that a specific business process must comply with?*

RQb): *What is the most suitable formalism and representation language for expressing both BPs and legal constraints in a unified way that supports their long-term integration and evolution?*

RQc): *What are the effects and implications of using AI in BPC from process, legal, and ethical perspectives?*

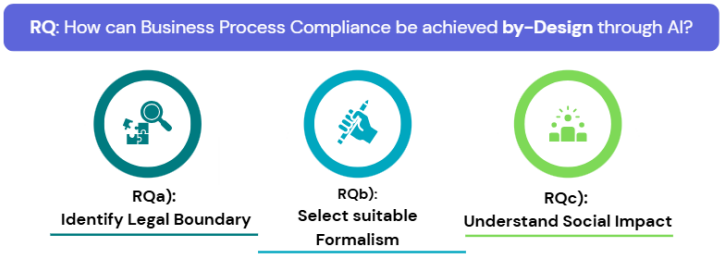

Figure 1: Research questions.

From the state of the art, the research gap in the adoption of AI for BPC emerges clearly, underlying the lack of a formal and reusable by-design approach to BPC. The recent renewed interest in this topic further highlights its relevance. Accordingly, the central research question **RQ** of this study focuses on how AI can be leveraged to achieve BPC by-design.

In particular, (**RQa**) explores how AI can determine which policies, regulations, and laws define the compliance boundaries of a process, given its characteristics, context, and domain of application.

Once these legal boundaries are defined, an appropriate language or formal notation must be selected to represent both the BP, according to a reference model, and its regulatory context. The integration between compliance rules and the target BP should then be supported by AI, taking into account reliability concerns while enabling more innovative solutions compared to current approaches (**RQb**).

Finally, the impact of AI-based BPC should be analyzed from process, legal, and ethical perspectives (**RQc**). These insights are crucial for improving AI-enabled compliance through a continuous improvement approach aligned with Kaizen principles [15].

3. Research Methodology and Techniques

We believe the most suitable methodology for this research is Design Science Research (DSR), as it integrates theoretical foundations with practical solution development. Accordingly, this research will follow a DSR-inspired approach as described by [16], structured into four sequential phases (Fig. 2).

The first phase, **Problem Explication**, focuses on defining the core problem: achieving BPC by-design through the use of AI as an enabling technology. This objective is particularly challenging as it must account not only for domain-specific rules and context-dependent regulations, but also for compliance with the EU AI Act [5]. To ground the research, this phase also includes a systematic literature review (SLR) on the application of AI for BPC to refine the research questions.

The **Requirements and Use Case Definition** phase relies on the results of the SLR not only to rigorously analyze the state-of-the-art, but also to derive the requirements for the proposed solution. In addition, a real-world use case will be selected to demonstrate feasibility. For example, a certification and installation process for a critical aircraft component (e.g., avionics system, flight actuator, or turbine) may involve multiple applicable regulations and standards.

The **Design and Development** stage focuses on creating the design science artifact that addresses the research questions. The outcome is a holistic framework for by-design BPC, aimed at preventing violations rather than detecting them after occurrence. Grounded in the literature, this phase involves designing or selecting AI tools to support human modelers, positioned as core components of the framework. If suitable tools are not available, new AI methods will be developed to assist in identifying and refining the relevant legal framework for a given context. For instance, in an aeronautical scenario, the framework must consider regulations from authorities such as the European Union Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA), as well as standards like AS9110, AS9120, and requirements related to safety, cybersecurity, and environmental compliance. The EU AI Act must also be incorporated, given the use of AI. Since no identified set of regulations can guarantee completeness, AI is used to improve the accuracy and precision of legal boundary identification. Once defined, the legal framework and compliance rules are translated into a form that can be integrated

with the BP and adapted over time. Finally, the implications of AI-enabled BPC are analyzed.

The **Demonstration and Evaluation** phase involves applying the methodology to the proposed use case to demonstrate the feasibility of the artifact. The solution is then assessed in terms of its effectiveness in addressing the identified problem and fulfilling the specified requirements.

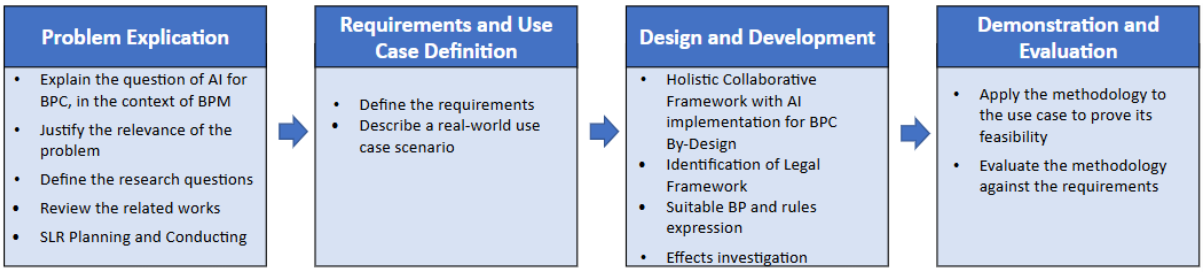

Figure 2: Research approach based on Design Science principles by [16].

4. Proposed Solution

The proposed solution to the main **RQ** in Section 2 is a *collaborative framework for responsible AI-enabled BPC*, developed through a Co-Design approach. Although several works define ethical principles for AI systems [17, 18], there is still no practical solution for embedding and operationalizing ethics in dynamic, real-world contexts. Existing challenges include the lack of actionable ethical knowledge and the vagueness of many principles. ECCOLA, for instance, supports ethical requirements engineering in Agile AI development by using card-based methods to derive ethical user stories [19].

From a regulatory perspective, the EU AI Act is not yet fully straightforward to apply due to delays in governance structures and the absence of fully harmonized standards for high-risk requirements. The European Commission's Digital Omnibus on AI introduces simplification measures to support a more practical and timely implementation [20]. Similarly, the EU AI Act classifies AI systems according to their level of risk and requires a Fundamental Rights Impact Assessment (FRIA) for high-risk systems to support the continuous identification and mitigation of potential risks [21]. Consequently, the proposed collaborative framework should incorporate a continuous risk management approach.

Additionally, from a legal standpoint, emphasis should be placed on liability allocation and on defining ethical principles governing AI behavior, which must be established ex ante through a by-design approach. A Co-Design strategy is particularly suitable, as it helps address responsibility concerns by involving stakeholders directly in system development. Employees using AI for BPC can thus participate in shaping and validating a tailored solution aligned with their regulatory context. This participatory process also supports better understanding and training in AI use, enabling continuous mutual learning between humans and the AI-based system. Over time, such collaboration can foster a virtuous cycle of adaptation, improving the operationalization of ethical principles within the organization. Furthermore, involving stakeholders in design can increase trust and facilitate adoption, whereas lack of engagement risks reducing AI initiatives to ineffective technological investments that overlook the human and organizational dimensions.

To address (**RQa**), our framework aims to identify and suggest the relevant set of regulations and laws for BPC, depending on the specific context. As full AI autonomy is not reliable in this task, a Human-in-the-Loop approach is essential to ensure trust and incorporate domain expertise, with human modelers acting as the primary experts.

(RQb) can be addressed by proposing a technique that takes as input: (i) a non-compliant BP model, typically expressed in a descriptive procedural language, and (ii) a domain-specific set of rules and constraints that vary according to the context. The goal is to properly represent the BP using a reference model and to formally express and translate legal and ethical requirements into a rule set that can be processed by the technique. As the objective is to achieve a genuine integration of AI and BPM for

BPC, the proposed technique will also inform the design of an AI-based tool. The expected outcome is a compliant BP aligned with its tailored legal perimeter and operating context. In this setting, AI-augmented BP autonomy is constrained at two levels: operational (procedural) and normative (deontic) [22]. Since constraints evolve over time, a key challenge is defining representations that support their integration and adaptation within the BP. This aspect forms part of the overall research objective. An example of the intended approach is the study [23], which introduces a maturity model for deriving GDPR-compliant BP models in BPMN. In this case, the inputs are the GDPR regulation, with its data protection obligations for data controllers, and a non-compliant BP model. The proposed method does not rely on AI, but instead uses BPMN design patterns associated with each GDPR obligation. By applying these patterns, the resulting output is a GDPR-compliant BP model. Likewise, this research plan aims to achieve by-design BPC not limited to specific regulations, but through an architectural framework that integrates multiple techniques and tools. The goal is to enable customization and adaptability to different domains, supporting the generation of compliant BP models by-design.

(RQc) can be addressed through an exploratory study designed to better understand the causal relationships and effects of AI adoption for BPC from process, legal, and ethical perspectives. A possible approach combines empirical methods, such as case studies and expert interviews, with process mining and simulation techniques to observe system behavior over time. This mixed-method analysis enables the identification of the major dependencies and supports a structured assessment of AI impact on compliance management.

5. Open Points and Concluding Remarks

This research focuses on designing and validating a by-design approach to BPC supported by AI. Some preliminary results have already been obtained, including an evaluation of the effectiveness of Large Language Models (LLMs) in supporting the identification of the relevant set of regulations with which a BP must comply **(RQa)**. These results will be presented during the BPM 2026 Forum track [24].

The current focus is on investigating **(RQb)** and **(RQc)**. Initial findings on **(RQc)** suggest that key open issues include the analysis of ethical implications and regulatory considerations, particularly in relation to the EU AI Act and other emerging technology regulations. The next steps foreseen in the roadmap of my PhD path will include an SLR focusing on AI instruments and BPC to refine the requirements of the solution. Moreover, a real-world scenario will be selected to investigate a particular application context and to demonstrate the feasibility of the by-design approach to AI-enabled BPC.

Some further challenges that may threaten the feasibility of this research plan include:

- *(i)* identifying the most suitable AI techniques for achieving the proposed outcomes, and potentially developing new ones when existing solutions are insufficient;
- *(ii)* defining the legal perimeter for BPC and ensuring its correct integration with business processes;
- *(iii)* managing evolving regulations and model updates over time to maintain alignment with changing real-world conditions.

To conclude, during the Doctoral Consortium, I aim to obtain feedback on the design and research methodology of the proposed approach, and on how to integrate the individual research questions into a coherent PhD dissertation.

Declaration on Generative AI. The author has not employed any Generative AI tools.

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