DOI: 10.32347/2412-9933.2025.62.12-23
UDC 005.8:[658.115.31:005.334]

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DATA-DRIVEN ERP-BPMS MODEL FOR PUBLIC UTILITIES' CRISIS RESILIENCE

Abstract. *Public utility enterprises (PUEs) increasingly operate in volatile environments characterized by geopolitical tensions, infrastructure disruptions, and workforce mobilization, all threatening essential services. This study proposes a hybrid risk management model integrating Enterprise Resource Planning (ERP) and Business Process Management Systems (BPMS) with heuristic decision-making and predictive analytics. Using a mixed-methods approach, we analyzed key performance indicators (KPIs) – including response times, resource utilization, and continuity – extracted from BOS CIS at Mastergaz (a Ukrainian utility). Pre- and post-integration comparisons showed a 50% reduction in response times, 20% lower logistical costs, and continuity above 90%. A qualitative thematic analysis of 15 interviews confirmed that improved transparency, preparedness, and decentralized decision-making aligned with these KPI gains. Scenario-based simulations (including Monte Carlo) validated the model under infrastructure loss and workforce shortages. These integrated findings support the hypothesis that an ERP-BPMS integrated model grounded in both quantitative and qualitative metrics enhances agility, cost-effectiveness, and resilience. This framework offers utility leaders a data-driven, adaptable tool for proactive crisis management across diverse scenarios.*

Keywords: crisis resilience; risk management; ERP-BPMS integration; public utilities; predictive analytics; heuristic decision making; resource allocation; operational continuity

Introduction

Public utility enterprises now face an unprecedented array of overlapping threats, ranging from geopolitical tensions and cyber incidents to sudden workforce mobilization and unexpected disruptions in critical infrastructure. Traditional manual frameworks, which rely on hierarchical decision making and predefined protocols, often lack the flexibility and real-time insights needed for today's fast-changing conditions. Consequently, many utilities struggle to optimize resource allocation, adjust to volatile staff availability, and predict emerging risks in ways that maintain operational continuity and public trust.

Recent research on Enterprise Resource Planning (ERP) and Business Process Management Systems (BPMS) has shown their potential for automating and integrating day-to-day operations. Mastergaz, a leading technical service operator in Kyiv, realizes these capabilities through a proprietary ERP-BPMS platform known as the BOS CIS. However, the focus was not solely on automation. In practice, the BOS CIS platform and human specialists monitor and enhance each other's work bi-directionally. The BOS CIS tracks incoming service requests, manages inventories, and issues data-driven suggestions for prioritizing tasks. Meanwhile, field technicians and management teams confirm or override these suggestions based on actual on-site conditions and established response protocols, providing qualitative feedback that the system incorporates into subsequent calculations. This synergy ensures that neither the automated workflows nor the human operators act in isolation; each cross-validates the others' inputs, leading to more adaptive and robust crisis responses.

To examine how these integrated ERP-BPMS capabilities perform in a real-world setting, this paper focuses on Mastergaz, a leading technical service operator in Kyiv. Mastergaz's custom platform, BOS CIS, combines automated data-driven workflows with on-site human oversight, providing a unique opportunity to observe how centralized information systems and decentralized decision making unfold under crisis conditions. By analyzing Mastergaz's operational protocols and crisis responses, we aim to illustrate both the practical challenges and tangible benefits of merging algorithmic recommendations with human expertise in highly volatile environments.

Although previous studies have documented how ERP-BPMS tools improve efficiency under stable conditions, few have examined their use in high-stakes scenarios, such as abrupt warehouse losses or employee mobilizations. To fill this gap, the present study analyzes the combination of automated processes and human-driven actions in Mastergaz. Using quantitative and qualitative data and scenario-based simulations, this study evaluated the extent to which a hybrid approach can shorten reaction times, reduce operational costs, and strengthen resilience against unpredictable disruptions. The findings confirm that combining automated resource allocation and real-time analytics with expert oversight, standardized checklists, and flexible decision protocols empowers public utilities to handle crises effectively. Thus, this study contributes a data-supported framework illustrating how ERP-BPMS systems complemented by human expertise and mutual cross-checking can help utilities adapt to intensifying operational challenges.

Analysis of latest research

Existing research highlights the growing complexity of modern crises, underscoring that top-down static management approaches are often too rigid for the escalating interplay of threats [1]. Such approaches struggle to keep pace with sudden shifts in demand and supply, leaving public utilities particularly vulnerable when disruptions intensify. An emerging consensus points to the potential of data-driven frameworks. Scholars, including Ensslin et al. [2], Peronja [3], and Lucas and Edwards [4] argue that integrating Enterprise Resource Planning (ERP) with Business Process Management Systems (BPMS) can centralize operational data and advance organizational learning; however, most of these studies focus on relatively stable conditions rather than high-stake, real-time crises.

Beyond these foundational works, other authors have addressed how ERP-BPMS solutions might support organizational agility and crisis readiness. Arbogast et al. [5] explore how the co-evolution of ERP and BPM fosters rapid adaptation, while Alves et al. [6] discuss engineering management scenarios that demand integrated frameworks for risk assessment. Amiri and Kazerooni [7] considered ERP designs tailored to public utilities, reinforcing the need for context-specific architectures. Houy et al. [8] (identify an emerging body of empirical BPM research but point out that its application in crisis scenarios remains limited. TohidiFar et al. [9] demonstrate how hybrid models can bolster resilience in hospital utility systems. Collectively, these contributions suggest that ERP-BPMS solutions, when adapted to high-pressure contexts, could help organizations reconfigure processes under stress.

One critical element of crisis management is balancing fast interventions with strategic governance. Haider and Rasli [10] argued that incorporating feedback loops is essential for iterative learning, which in turn supports crisis resilience. Abimbola and Khan [11] showed that multi-criteria decision-making (MCDM) enables utilities to holistically weigh financial, operational, and reputational risks, ensuring that rapid actions align with long-term stability.

Kapur et al. [12] present advanced algorithms for enhancing decision quality. Lei et al. [13] and Linna et al. [14] emphasize the importance of reconceptualizing vulnerability, resilience, and adaptation within comprehensive risk frameworks, as reflected in Nawaz et al. [15] with regard to demand-side management in smart grids. Meanwhile, Hassanein [16] underscore that although automation boosts efficiency, human oversight is indispensable for context-sensitive decisions. Manab and Aziz [17] highlight the significance of knowledge management in sustaining resilience, while Landegren et al. [18] and Lei et al. [13] focus on assessing network robustness.

Despite these insights, real-life examples of how ERP-BPMS integration can respond instantly to severe disruptions remain sparse [19, 20]. While Zafar et al. [21] and Kilic et al. [22] confirm that ERP's adaptability and BPM's flexibility can handle sudden shifts, few have shown precisely how such tools operate under pressures, such as workforce mobilization or warehouse failure. This gap is critical because it overlooks how system-generated analytics and human-driven interventions might converge in practice. Although various crisis scenarios, ranging from supplier breakdowns to regulatory upheavals, are covered in the literature, empirical research documenting the performance of ERP-BPMS in scenarios such as abrupt staff deployment or physical asset loss is limited. Similarly, the interplay between automated recommendations and staff expertise (protocols, checklists, and local knowledge) has seldom been explored in detail.

Most existing works remain theoretical or focus on narrow performance indicators without thoroughly incorporating qualitative organizational insights. Therefore, researchers lack a robust, practice-oriented framework to guide strategic planning and hands-on crisis operations. Addressing this methodological gap is especially relevant for public utilities with high stakes, in terms of continuity and safety. By integrating quantitative evidence (e.g., improvements in key performance indicators (KPIs) and scenario testing) with qualitative perspectives (e.g., interviews and thematic analysis), scholars can provide a more comprehensive view of how ERP-BPMS systems infused with predictive modeling and MCDM can be adapted for high-impact events such as workforce mobilization or warehouse disruptions.

Collectively, these studies highlight the need for a robust and adaptable approach that integrates ERP, BPM, predictive analytics, and human-driven oversight to manage crises in public utilities. While the literature underscores potential advantages, such as faster response times, improved resource allocation, and proactive risk mitigation, there remains a gap in demonstrating how these components synergize in actual high-stake events. Building on these insights, the next section presents our theoretical framework and hypotheses, positioning ERP-BPMS integration as a data-driven yet context-sensitive model capable of handling acute disruptions in public utilities.

Purpose of the article

The purpose of the research is to develop a hybrid risk management model that combines enterprise resource planning (ERP) and business process management (BPMS) systems with heuristic decision-making and predictive analytics.

The main material of the article

Recent discussions on resilience engineering and crisis management suggest that public utilities can benefit from integrated digital solutions that merge operational data with flexible process controls [1]. In parallel, enterprise resource planning (ERP) frameworks emphasize centralized data management and streamlined workflows [7], while business process management systems (BPMS) focus on modeling and continuously improving organizational processes [8]. Research has increasingly highlighted the potential of blending ERP functionality with BPM principles to achieve not only efficiency but also agile responsiveness in uncertain environments [2; 21].

When applied to crisis scenarios, this merger promises real-time situational awareness and automated decision support, aligning with broader theoretical insights into adaptive sociotechnical systems [23]. ERP systems centralize resource and operational data, whereas BPMS platforms define, automate, and refine workflows. This combination allows predictive analytics to function on a richer dataset, enhancing the organization’s capacity to anticipate disruptions [10]. Heuristic decision-making processes augment algorithmic outputs by incorporating expert judgment, thus fostering resilience in rapidly changing contexts.

Based on these theoretical perspectives, this study posits that data-driven ERP-BPMS integration will improve both immediate crisis responses and long-term recovery strategies in public utilities. The framework assumes that automation, where suitable, reduces reaction times and resource misallocation, whereas human oversight ensures contextual nuance and strategic alignment. To test these assumptions, we examined the following three core hypotheses:

H1: ERP-BPMS integration significantly reduces crisis response times by streamlining information flows and automating resource allocation.

H2: Predictive analytics and heuristic decision-making built into an ERP-BPMS framework lower operational costs during crises without compromising service quality.

H3: Decentralized decision making, supported by robust ERP-BPMS data analytics, enhances overall service continuity by enabling local teams to adapt rapidly to emerging threats.

These hypotheses are derived from prior literature on integrated crisis management systems [24], underscoring the need for centralized data analysis and decentralized enactment of solutions. By explicitly linking the theoretical constructs of ERP and BPM integration with crisis-resilience strategies, the model anticipates that combining algorithmic recommendations, predictive models, and staff-led protocols will create a dynamic ecosystem capable of coping with acute disruptions. The subsequent empirical investigation in this study explores whether these theoretical propositions hold true in real-world settings using Mastergaz as the pilot context.

This study employed a mixed-method design to evaluate the proposed ERP-BPMS integrated model in a public utility setting. Mastergaz, a Ukrainian utility that manages over 750,000 client accounts and processes approximately 200 to 300 daily service requests, provides the primary case. Quantitative data were drawn from the BOS CIS, the central information system used by Mastergaz, which logs crisis response times, resource utilization rates, and service continuity metrics. Historical figures spanning six months before and after system implementation established baseline and post-integration reference points, focusing on scenarios involving workforce mobilization and warehouse disruptions. Because the BOS CIS is configured primarily for routine operations, any additional breakdowns or custom views required for research purposes were extracted into Microsoft Excel spreadsheets, where the research team performed descriptive and comparative statistical analyses, including the calculation of mean values, relative changes, and simple t-tests for differences in average response times and downtime.

Qualitative data emerged from 15 semi-structured interviews with a cross-section of crisis management personnel, including operations managers, logistics coordinators, and frontline technicians, who had encountered recent events requiring immediate intervention. The sample size reached theoretical saturation by the fourteenth interview, which is in line with established guidelines for qualitative inquiry [25]. Interviews typically lasted 45–60 minutes, followed by institutional review board standards for informed consent and confidentiality. They were recorded and transcribed verbatim, after which the transcripts were subjected to thematic analysis. The coding process began with an initial reading of the transcripts to identify recurrent concepts, followed by more focused coding of relevant passages that aligned with the crisis response, decision-making structures, and perceived value of ERP-BPMS features. Two researchers examined these codes independently to enhance inter-coder reliability, and discrepancies were resolved through iterative discussions. The final themes were validated by cross-referencing them with the quantitative results to determine whether the narratives explaining the shortened response times, improved resource allocation, and increased preparedness matched the observed KPI shifts.

In addition to these interviews, scenario-based simulations further tested whether the integrated system can handle severe disruptions under controlled conditions. Monte Carlo simulations, run through a mix of BOS CIS's predictive modules and Excel-based randomization scripts, examined how inventory and workforce capacity might be reallocated during hypothetical warehouse failures or sudden staff shortages. Statistical data on these simulated outcomes were compared against historical performance and industry benchmarks, allowing for a structured evaluation of the capacity of the ERP-BPMS platform to adapt to worst-case scenarios. This approach permitted a clear assessment of whether the observed improvements in KPI values coincided with tangible changes in organizational behavior and crisis management culture.

The BOS CIS platform continuously aggregates operational data and triggers predictive alerts when certain thresholds or anomaly patterns appear, enabling comparisons between forecasted risk levels and actual incidents. All data collection complied with ethical principles, ensuring no disclosure of sensitive personal information and maintaining anonymity of interview participants. This study provides a comprehensive evidence base by combining quantitative measures (e.g., mean response times and relative cost reductions) with rigorously coded qualitative feedback (e.g., staff perspectives on trust in automation and decentralized authority). These data integration steps support the overarching aim of assessing whether the hybrid ERP-BPMS framework strengthens resilience and resource management, especially regarding high-impact issues, such as warehouse loss and workforce mobilization.

This study employs a convergent parallel mixed-methods design [25] to evaluate how an ERP-BPMS framework can strengthen crisis resilience in public utility enterprises. Mastergaz, a Ukrainian utility servicing over 750,000 clients, was selected due to its extensive operational scope and continuous exposure to critical disruptions such as warehouse losses and workforce mobilization. This setting served as a practical laboratory for observing how BOS CIS, Mastergaz's custom ERP-BPMS platform, functions under volatile conditions. Population and sampling strategies targeted individuals directly involved in crisis management, including operations managers, logistics coordinators, and frontline technicians, thus ensuring multiple perspectives. The choice of Mastergaz stemmed from its diverse crisis experiences, real-time data availability, and established internal protocols that could be compared before and after ERP-BPMS integration, thus maximizing ecological validity and replicability [1].

Data Collection:

1. Quantitative Data. The first phase of data collection centered on extracting key performance indicators (response times, resource utilization, and service continuity rates) from the BOS CIS for a six-month period before and after the implementation of the ERP-BPMS. These metrics establish pre- and post-integration baselines across various operational conditions. Because the BOS CIS was primarily configured for routine operations, any additional breakdowns or aggregated views were exported into Microsoft Excel for further analysis, including descriptive statistics (mean values, relative changes) and simple t-tests to identify significant differences in response times or downtime.

2. Qualitative Data. The second phase employed qualitative methods by conducting 15 semi-structured interviews with staff who had managed or responded to crises following a purposeful sampling approach [26]. This sample included operations managers, logistics coordinators, and frontline technicians from multiple organizational tiers, each offering insights into how automated workflows, checklists, and expert judgments interact in decision making. The interviews lasted 45–60 minutes, adhered to institutional review board standards for informed consent and confidentiality, and were recorded and transcribed verbatim. This phase deepened the understanding of how BOS CIS alerts blend with staff-led interventions and how human discretion adjusts automated outputs when on-site conditions deviate from the system assumptions.

3. Scenario-Based Testing. In the third phase, a multi-scenario analysis replicated the test conditions for each crisis scenario (e.g., warehouse loss and workforce mobilization) to confirm the robustness and reduce anomalies [27]. Parallel Monte Carlo simulations introduced hypothetical warehouse failures or workforce shortfalls to measure the changes in cost efficiency and service continuity. By comparing the simulation outputs

with historical performance data, the study assessed whether the observed KPI improvements mirrored actual organizational behavior shifts.

Data Analysis:

1. Statistical and Descriptive Methods. Quantitative data extracted from BOS CIS and processed in Excel were used for descriptive analysis to determine the mean response times, resource utilization ratios, and operational continuity percentages. Comparative analyses, such as calculating relative changes or applying simple t-tests, revealed that post-integration improvements (for instance, a 50% reduction in response time) were statistically significant. This approach preserves methodological rigor by separating the pre- and post-integration datasets until final consolidation [28].

2. Thematic Analysis. Qualitative interview transcripts underwent thematic analysis, beginning with an initial open coding pass to isolate major themes related to staff perceptions of automation, decentralization, and heuristic oversight. Two researchers independently coded key passages, and discrepancies were resolved through iterative discussions to enhance inter-coder reliability. The resulting themes (e.g., trust in data-driven suggestions and preparedness driven by predictive alerts) were cross-checked against quantitative indicators, verifying that the narratives aligned with the KPI trends observed in BOS CIS.

3. Simulation-Based Evaluation. Monte Carlo simulations, performed using a mix of BOS CIS's predictive modules and Excel-based randomization scripts, tested whether the integrated model could handle worst-case disruptions. The model introduced sudden resource shortages or infrastructure failures, and system reactions, such as reassigning staff or reallocating inventory, were monitored for cost efficiency and speed. By benchmarking these metrics against historical data and industry norms, this study gauged whether predictive analytics, heuristic rules, and human oversight jointly mitigated the large-scale crises.

To clarify how these components function together, Table 1 outlines the main modules and their roles during high-stake incidents. This helps to illustrate the synergy among ERP-BPMS automation, predictive forecasting, and staff-led interventions.

By merging automation (ERP-BPMS) with heuristic decision-making and predictive analytics, the system supports immediate responsiveness and long-term resource stability [13]. For instance, if the BOS CIS detects a warehouse outage, the BPMS workflow engine applies rule-based allocations (e.g., critical items relocated first), while the predictive module forecasts future supply or labor gaps. Human managers can override automated prescriptions if local conditions deviate from system assumptions, thereby ensuring that data-driven processes retain sufficient contextual nuances.

Building on the conceptual model (Figure 1, mind map of crisis scenarios), this study adopted a simplified mathematical framework for adaptive resource allocation.

Let $r_i(t)$ denote the allocated resources to scenario i at time t and w_i represent the weighted criticality of that scenario. The system calculates an allocation score $a_i(t)$ for scenario i by combining real-time data $x_i(t)$ with heuristic adjustments $h_i(t)$ as follows:

$$a_i(t) = w_i(t) \times x_i(t) + h_i(t).$$

Scenarios with higher $a_i(t)$ received priority in staff assignments, inventory deployment, or logistical support. In the long term, the model refines resource adaptation by incorporating predictive forecasts $p_i(t+\Delta t)$ for each scenario i over a future interval Δt.

*Table 1 – **Key Components of the Integrated ERP-BPMS Mode***

Component	Function	Example in Crisis
ERP Core (BOS CIS)	Centralizes data on inventory, workforce, and tasks	Flags disruptions (e.g., abrupt warehouse outage) and updates relevant logs in real time
BPMS Workflow Engine	Automates routine processes and routes critical alerts	Assigns technicians to priority tasks, updates dashboards, and notifies key managers
Heuristic Decision Rules	Provides rule-based prioritization and local overrides	Labels tasks as "essential within 2 hours" or "non-essential," allowing managers to override as needed
Predictive Analytics Module	Forecasts potential disruptions and resource shortfalls	Predicts workforce shortages 24 hours ahead, suggests reallocation strategies based on real-time data
Human Oversight	Validates or revises system recom-menddations based on on-site insights	Field managers confirm or modify automated reassignments, offering feedback to refine heuristics

Source: Authors' own work

The system adjusts allocations by the factor $f_i(t)$, which considers cost $c_i(t)$, continuity $u_i(t)$, and reputational risk $r_i(t)$ based on multi-criteria weighting [29]:

$$f_i(t) = a \times c_i(t) + \beta \times u_i(t) + \gamma \times r_i(t),$$

where *α, β*, and *γ* capture Mastergaz's strategic priorities (e.g., 40% financial, 30% operational, and 30% stakeholder trust). The updated allocation function for scenario *i* is:

$$r_i(t + \Delta t) = r_i(t) + a_i(t) \times p_i(t + \Delta t) \times f_i(t).$$

This formula ensures that real-time alerts and heuristic inputs are merged with predictive forecasts, creating a flexible resource-deployment scheme that adapts to evolving crisis states. In essence, the system fuses immediate rule-based responses with probabilistic projections, whereas managers maintain the ability to override final allocations if situational data suggest deviations from the model's assumptions [13].

As illustrated in Figure, the integrated hybrid model blends immediate response modules (heuristic rules and emergency reallocation) with long-term analytical functions (predictive modeling and resource adaptation). A multi-criteria analysis balances financial impact, operational continuity, and stakeholder trust [11; 29]. Decentralized management grants local team autonomy, whereas strategic oversight aligns decisions with organizational goals. Continuous feedback loops ensure that staff experience refines heuristic protocols and thresholds for alerts.

By partitioning data collection and analysis and by clearly outlining how ERP-BPMS, heuristic decision-making, and predictive analytics interlock in crisis scenarios, this methodology provides a replicable framework for evaluating or scaling similar models in other public utility contexts.

This section summarizes the implementation of the ERP-BPMS model in Mastergaz, drawing on quantitative KPI data, scenario simulations, inventory distribution metrics, multi-criteria decision-making (MCDM) outcomes, and qualitative insights from interviews with Mastergaz personnel. The analysis focuses on two high-impact crisis scenarios, warehouse loss and workforce mobilization, to illustrate how ERP-BPMS integration can improve resilience in public utilities.

The quantitative results center on system-level performance metrics, whereas the qualitative interviews provide a contextual understanding of how real-time data, decentralized decision-making, and staff-driven protocols influence operational behavior.

By merging these two perspectives, this study offers a nuanced view of crisis management enhancements, resource allocation efficiency, and organizational adaptability under challenging conditions.

The quantitative findings derived from the BOS CIS metrics and scenario simulations show marked improvements. The mean response times, resource utilization ratios, and operational continuity rates were compared before and after ERP-BPMS integration and expressed as percentage gains relative to baseline values. The response times decreased from an average of approximately 6 h to approximately 2 h, a reduction of approximately 50%, and the operational continuity increased from approximately 82% to 90%. These outcomes strongly support H1, which proposes that ERP-BPMS integration significantly reduces crisis response times by centralizing information flows and automating allocation decisions. This direct drop from 5–7 h to approximately 1–3 h aligns with prior theoretical expectations that faster data-driven feedback loops expedite the crisis response. The MCDM indices capture balanced progress across financial, operational, and reputational considerations.

Qualitative interviews reinforced these improvements by revealing enhanced trust in automated decision-making, greater preparedness due to predictive alerts, and increased autonomy for local units. Interviewees highlighted that staff perceptions and behavioral changes were closely aligned with the numerical KPI gains, demonstrating around a 20 % cost reduction, closely matching the theoretical premise of H2 that predictive analytics and heuristic decision-making can minimize expenditures without degrading service quality. In line with [2], the interplay between algorithmic forecasts and human oversight ensures that resources are not under- or over-allocated during disruptions, thus fulfilling the cost efficiency goal defined in our framework [2].

Before ERP-BPMS features were introduced into BOS CIS, Mastergaz often relied on manual intervention. Routine activities, such as inventory tracking and workforce scheduling, were handled effectively. However, when major disruptions occurred, response times increased, resources were often misallocated, and managerial oversight lagged. Staff-driven checklists are not formally integrated with real-time system data, which limits the potential for predictive insights. Table 2 provides the key performance metrics before and after ERP-BPMS integration. For each crisis event logged in BOS CIS, response times (in hours) were aggregated by dividing the total hours by the number of incidents over six months. Resource utilization efficiency was measured as the ratio of active assets to total available capacity. Relative differences, such as a 50% drop in response time, were calculated by comparing pre-and post-integration means with standard deviations examined to ensure consistency across multiple incidents.

Pre-integration interviews corroborated these limitations. Participants described how manually adjusting inventory and workforce allocation was slow and lacked predictive capacity, resulting in inefficiencies, extended downtimes, and lower customer satisfaction.

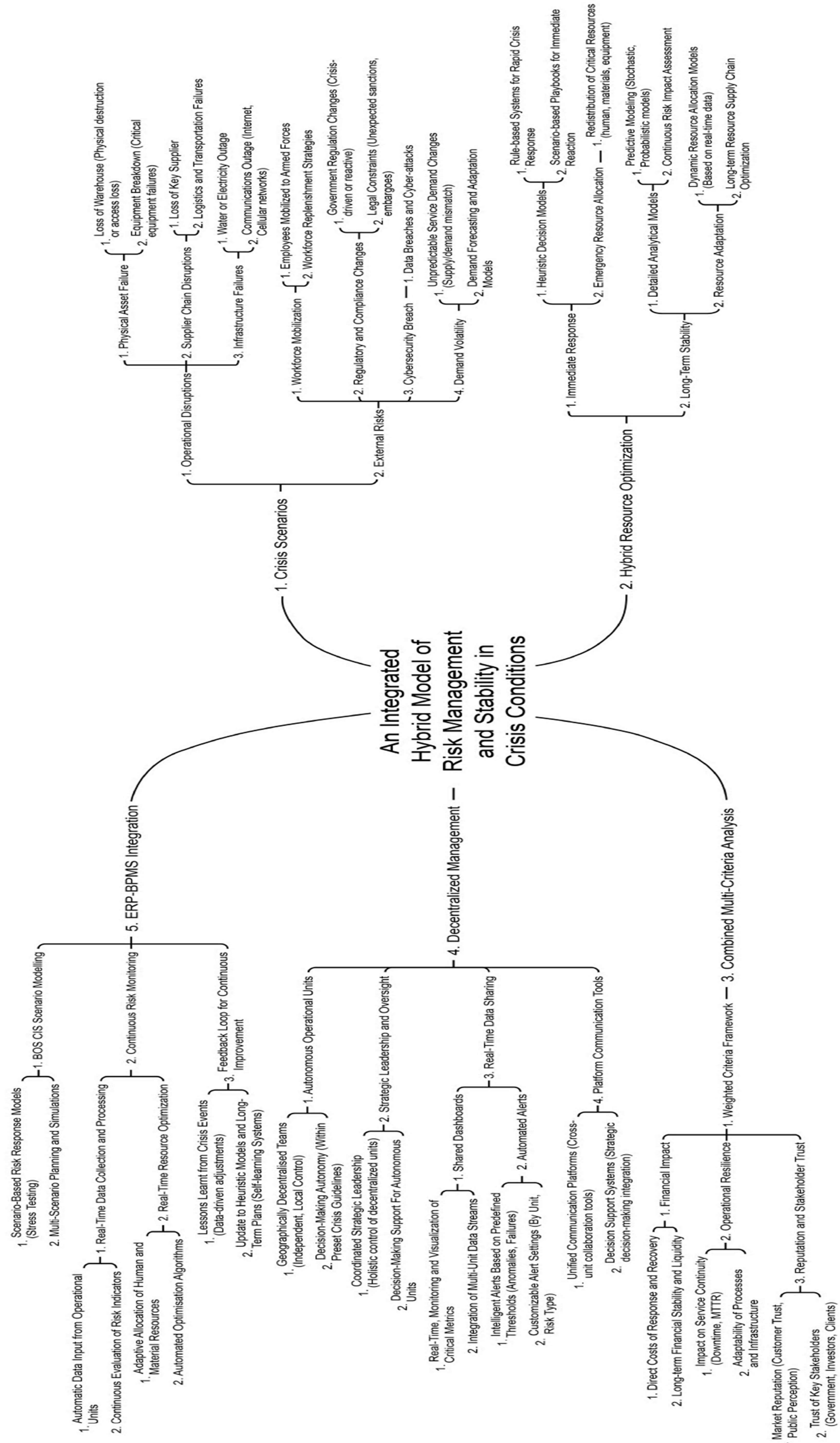

Figure – Integrated Hybrid Model of Risk Management and Stability in Crisis Conditions

Source: Authors' own work

Once the crisis-resilient ERP-BPMS model was fully embedded in the BOS CIS, Mastergaz observed major improvements. Automated resource allocation ensured rapid reassignment of inventories and workforce tasks, whereas predictive analytics offered early disruption warnings and allowed decentralized units to act swiftly within strategic guidelines. The response times fell between 1 and 3 h, operational downtime decreased from 20 to 8 h a month, and customer satisfaction rose to 90 %. Post-integration interviews highlighted an expanded sense of transparency and confidence among staff, with logistics coordinators indicating that real-time dashboards and predictive tools replaced guesswork and improved overall efficiency.

One critical indicator of crisis resilience is the effective allocation of inventories under severe constraints. Before integration, some warehouses carried excessive stock, whereas others operated at dangerously low levels. After implementing dynamic inventory models and heuristics, Mastergaz increased the inventory tracking accuracy (ita) to above 90 % and reduced the misallocation. The logistical cost efficiency (LCE) metric revealed approximately 20% lower costs during crises, confirming that well-calibrated resource distribution and predictive modeling can minimize expenses while maintaining service quality. This result closely maps onto H2, which suggests that predictive analytics and heuristic decision processes lower operational costs in crisis conditions. To handle the financial, operational, and reputational considerations inherent in high-impact events, Mastergaz used MCDM frameworks [11] and assigned weights of 40% to financial stability, 30% to operational continuity, and 30% to stakeholder trust. Post-integration analyses showed a 25% increase in the composite MCDM index, reflecting more balanced, strategically sound decisions.

The model's predictive capacity was evident in how it detected workforce shortages 24 h before they became critical, allowing time for temporary hires and resource shifts. Supply chain issues that had previously been tackled only after they arose were forecasted, thus enabling proactive redistribution. Monte Carlo simulations tested the adaptability of the system to extreme conditions, including sudden infrastructure losses, and confirmed that predictive modeling and heuristic decision-making substantially lowered restoration times and costs. Interviews corroborated this evidence, with staff noting that they felt more prepared and less reactive, an attitude that promoted a more resilient organizational culture. By enabling decentralized units to respond rapidly based on real-time data and local know-how, these findings reinforce H3, which posits that decentralized decision making, supported by robust ERP-BPMS data analytics, enhances service continuity. This mirrors resilience theories [23], which suggest that local autonomy underpinned by real-time metrics can preserve high operational continuity in diverse crisis scenarios.

Case Study 1, focusing on a March 2022 missile strike that damaged a key warehouse and an office, underscored the vulnerability of centralized logistics. Without the ERP-BPMS model, it took 12 h to relocate critical items, affected 35% of client services, and required 96 h for full restoration. These disruptions prompted a shift toward a decentralized infrastructure and the adoption of predictive and heuristic tools. Table 3 shows how simulations estimated that the new approach could relocate inventory in 3 h rather than 12 h, reduce affected services from 35% to 10%, and reduce restoration time from 96 to 48 h while reducing logistical expenses by 20%. Interviews with crisis managers demonstrated that seeing these potential outcomes motivated strategic investments in decentralized offices and BOS CIS enhancements.

Case Study 2 examined a persistent challenge in the form of workforce mobilization into the Armed Forces. In the absence of predictive analytics and timely reallocation, staff shortages have immediate negative effects on efficiency and service reliability. With the ERP-BPMS, Mastergaz could anticipate skill gaps, activate standby labor 24 h earlier, and lower downtime from 20 to 8 h a month, thereby sustaining approximately 90% operational efficiency. Interviewees from human resources noted that, despite the inevitability of mobilization, BOS CIS dashboards clarified emerging skill deficits and supported rapid task reassignments, including targeted hires of technicians, students, retirees, or demobilized military personnel. This approach stabilized task completion rates and customer satisfaction, even with a diminished workforce.

Qualitative analysis offers a deeper explanation of why these gains occurred. The staff observed that what had formerly been reactive processes turned into proactive planning, echoing the role of predictive analytics in anticipating resource needs and further validating H2. Resource redistribution was viewed as both fair and logical, largely because of MCDM-guided decisions, which built employee trust.

These observations align closely with the KPI improvements, indicating that the benefits extend beyond simple numerical gains to deeper shifts in culture, decision making, and forward planning.

The final step involved linking these qualitative insights to quantitative outcomes. The interviews revealed that operational transparency and trust improved once the data silos were replaced by unified, real-time dashboards.

This heightened trust correlated directly with shortened response times and lower downtimes, as shown in Tables 2 and 3. The staff also reported a sense of preparedness driven by early forecasting capabilities, matching shorter inventory relocation times. Decentralized decision-making empowers field teams to resolve smaller issues locally before escalating, thereby reducing the overall impact of disruptions.

Table 2 – ***Comparative analysis of key performance metrics before and after crisis resilient ERP-BPMS model integration at Mastergaz***

Metric	Before Integration	After Integration
Response Time to Crises (hrs)	5–7	1–3
Resource Utilization Efficiency (%)	75	90
Operational Downtime (hrs/mo)	20	8
Customer Satisfaction (%)	82	90
Task Reallocation Time (hrs)	2	0.5

Source: Authors' own work

Table 3 – ***Simulated Impact of ERP-BPMS Implementation on Key Performance Metrics During Infrastructure Loss Scenario***

Metric	Pre-Implementation	Post-Implementation (Simulated)
Time to Relocate Critical Inventory (hrs)	12	3
Percentage of Client Services Affected (%)	35	10
Total Service Restoration Time (hrs)	96	48
Projected Logistical Cost Savings (%)	—	20

Source: Authors' own work

Balanced automation and human oversight, in which automated resource reallocations can be overridden or confirmed by managers, preserving contextual nuances during high-risk events. These cross-validations confirm that the metrics in the tables are consistent with both the narratives provided by respondents and simulation results, reinforcing the core assertions of H1, H2, and H3.

From a broader perspective, the four key aspects of these findings are especially relevant. First, the model appears highly scalable, adapts easily from warehouse disruptions to workforce shortages, and suggests the possibility of replicating similar outcomes in other public utilities. Second, the 20% cut in crisis-related costs not only offers financial relief but can also funnel resources into preventive measures and service enhancements, thereby strengthening public trust. Third, continuous improvement loops indicate that the model evolves alongside each new crisis, refining data inputs and heuristic protocols over time. Fourth, the flexibility to incorporate emerging threats from cyber-attacks into regulatory shifts underlines the model's long-term strategic value.

Overall, these results confirm the primary hypothesis that merging ERP-BPMS integration with heuristic decision-making and predictive analytics improves resource allocation efficiency and reduces resilience expenditure for public utility enterprises during crises. The findings specifically validate H1 by demonstrating a significant decrease in response times, H2 by showing a measurable drop in operational costs paired with maintained service quality, and H3 by highlighting improvements in decentralized control and service continuity. Taken together, these operational gains, supported by real-world case studies and scenario simulations, underscore the framework's versatility and robustness.

These findings indicate that integrating enterprise resource planning with business process management systems can significantly enhance crisis resilience in public utility enterprises. By merging heuristic decision making, predictive analytics, and a decentralized operational structure, the proposed model addresses common obstacles in traditional crisis frameworks, including slow reaction times, static decision protocols, and inefficient resource deployment. This outcome corroborates H1, which suggests that ERP-BPMS integration leads to reduced crisis response times and more effective resource allocation.

The quantitative and qualitative results show that this ERP-BPMS model markedly improves response times, continuity of operations, and cost-effectiveness, especially in scenarios involving warehouse losses and workforce mobilization. At Mastergaz, the response times declined from 5–7 h to 1–3 h, enabling the company to maintain over 90% operational continuity even under severe conditions. These results align with prior research on real-time data and process automation to minimize crisis disruptions [24]. A 20% reduction in logistical expenses, confirmed through multi-criteria decision making [30], reinforces H2, which posits that predictive analytics and heuristic protocols can lower operational costs without sacrificing service quality.

Predictive workforce management capabilities further underscore the model's adaptability by anticipating labor shortages and reallocating tasks, preserving efficiency despite workforce mobilization. Decentralized decision making adds agility and situational relevance, resonating with Zafar et al. [21] on the benefits of a localized ERP-based crisis response. Supported by robust data-driven insights, this approach validates H3 by demonstrating how autonomous units can maintain overall service continuity. Staff protocols and checklists complement ERP-BPMS analytics, ensuring that human discretion and contextual judgment remain integral in high-stake decisions.

The integrated feedback loops observed at Mastergaz support the principle that iterative refinement promotes greater resilience [10]. The organization's ability to scale this model aligns with Shafiee et al. [23], who highlight ERP-BPMS as capable of managing a variety of disruptions in complex infrastructure. Taken together, these quantitative and qualitative indicators provide tangible evidence that the integrated ERP-BPMS framework, along with heuristic and predictive modules, fulfills the theoretical expectations set out in H1, H2, and H3. By demonstrating faster response times, lower operating costs, and improved service continuity, the findings confirm the model's potential for addressing complex crises in alignment with earlier literature on adaptive socio-technical systems.

Although this single-case pilot study provides in-depth insights, it also restricts the generalizability of the findings, particularly for utilities operating under different regulatory frameworks or technological infrastructures. The reliance on Mastergaz's BOS CIS logs and a limited sample of key personnel may introduce bias if certain departments or viewpoints are underrepresented. Additionally, improvements in KPIs may have been partially influenced by contextual factors such as seasonal demand fluctuations or concurrent policy changes. Future research could address these concerns by adopting multi-case comparative designs or longitudinal studies that track ERP-BPMS performance across diverse utility settings. Incorporating advanced machine learning algorithms or exploring alternative crisis scenarios, such as cyber-attacks or demand surges, would further clarify how predictive analytics and heuristic decision making evolve over time.

For utility managers, the results highlight the need for a systematic roadmap for adopting ERP-BPMS platforms with embedded predictive modules. Training is essential to ensure that technicians and mid-level managers can interpret automated recommendations and refine heuristic protocols, particularly when local conditions deviate from the system assumptions. Collaboration between policymakers and stakeholders can streamline the integration of such systems into existing emergency plans, thereby improving transparency, risk mitigation, and resource allocation. By continually updating the underlying algorithms and checklists to reflect ongoing operational data, public utilities can maintain an adaptive data-driven environment that remains resilient in the face of emerging threats.

In terms of theory, this work advances ERP and BPM scholarship by examining these frameworks under acute crisis conditions rather than stable day-to-day operations [2]. This demonstrates that a hybrid approach – algorithmic decision making supported by human oversight – can enhance organizational resilience and real-time responsiveness, extending existing crisis management models that often emphasize either purely automated or hierarchical approaches. The findings bridge a key gap in the literature by showing how socio-technical resilience can be operationalized via integrated data analytics, heuristic protocols, and decentralized operational structures, thereby contributing novel insights into the intersection of ERP, bpm, and crisis resilience.

In summary, the synergy of predictive analytics, heuristic oversight, and decentralized control significantly improves performance in warehouse disruption and workforce mobilization scenarios. Although additional case studies and longitudinal research are warranted, this single-case evidence strongly suggests that an ERP-BPMS hybrid model can be both theoretically and practically transformative. By combining automation with expert judgment, public utilities can better protect critical services and sustain operational continuity in an increasingly volatile world.

Conclusions

This study examined whether integrating ERP-BPMS with heuristic decision-making and predictive analytics could improve resource allocation efficiency and reduce resilience expenditures in public utility enterprises during crises. Focusing on two critical scenarios, warehouse loss and workforce mobilization, in Mastergaz, the results showed a marked reduction in response times (from 5 to 7 h to 1–3 h), maintenance of over 90% operational continuity, and a 20% decrease in logistical costs. These quantitative gains coincide with qualitative evidence of enhanced transparency, staff confidence in data-driven protocols, and more effective decision making. Thus, the convergence of automation and expert oversight offers an agile, data-centric alternative to rigid, manual frameworks.

While this single-case design and reliance on BOS CIS logs may limit the generalizability of the findings, this study provides a robust foundation for advancing crisis management strategies in public utilities. Future studies could replicate the approach in multiple sites or sectors, explore advanced machine learning models for predictive analytics, or refine protocols for balancing automated workflows with human expertise in more varied crisis contexts. Extensions to domains such as healthcare, transportation, and energy infrastructure could further illuminate the adaptability of the hybrid model under divergent regulatory and operational conditions.

By bridging the theoretical gaps in ERP-BPMS research and offering practical guidance for utility leaders, this study demonstrates that a hybrid framework can safeguard critical services and bolster operational resilience under high-stakes disruptions. In an era marked by global uncertainties and escalating systemic risks, synergy between data-driven automation and human judgment has emerged as a compelling strategy to ensure that public utilities remain reliable cornerstones of societal well-being.

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The article has been sent to the editorial board 04.04.2025

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МОДЕЛЬ ERP-BPMS НА ОСНОВІ ДАНИХ ДЛЯ ЗАБЕЗПЕЧЕННЯ КРИЗОВОЇ СТІЙКОСТІ КОМУНАЛЬНИХ ПІДПРИЄМСТВ

Анотація. *Комунальні підприємства (КП) все частіше працюють у нестабільному середовищі, яке характеризується геополітичною напруженістю, перебоями в роботі інфраструктури та мобілізацією робочої сили, що ставить під загрозу надання основних послуг. У цьому дослідженні пропонується гібридна модель управління ризиками, що поєднує системи планування ресурсів підприємства (ERP) та управління бізнес-процесами (BPMS) з евристичним прийняттям рішень і прогнозною аналітикою. Використовуючи змішаний підхід, ми проаналізували ключові показники ефективності (KPI), включаючи час реагування, використання ресурсів та безперервність, отримані з системи BOS CIS в компанії «Мастергаз» (українське комунальне підприємство). Порівняння до і після інтеграції показало скорочення часу реагування на 50%, зниження логістичних витрат на 20% і підвищення безперервності на 90%. Якісний тематичний аналіз 15 інтерв'ю підтвердив, що покращення прозорості, готовності та децентралізованого прийняття рішень узгоджуються з цими досягненнями KPI. Сценарні симуляції (в тому числі за методом Монте-Карло) підтвердили правильність моделі в умовах втрати інфраструктури та дефіциту робочої сили. Ці комплексні результати підтверджують гіпотезу про те, що інтегрована модель ERP-системи управління підприємством, яка ґрунтується на кількісних та якісних показниках, підвищує гнучкість, економічну ефективність та стійкість. Ця система пропонує керівникам комунальних підприємств адаптивний інструмент для проактивного антикризового управління за різних сценаріїв, що базується на даних.*

Ключові слова: кризова стійкість; управління ризиками; інтеграція ERP-BPMS; комунальні послуги; прогнозна аналітика; евристичне прийняття рішень; розподіл ресурсів; операційна безперервність

Link to publication

APA Chernenko, Yu., Semko, A., & Berezenskyi, R. (2025). Data-driven ERP-BPMS model for public utilities' crisis resilience. *Management of Development of Complex Systems*, 62, 12–23, dx.doi.org\10.32347/2412-9933.2025.62.12-23.

ДСТУ Черненко Ю. В., Семко О. В., Березенський Р. В. Модель ERP-BPMS на основі даних для забезпечення кризової стійкості комунальних підприємств. *Управління розвитком складних систем.* Київ, 2025. № 62. С. 12 – 23, dx.doi.org\10.32347/2412-9933.2025.62.12-23.