

RISK MANAGEMENT IN THE PROCESS OF LIBRARY TECHNOLOGIZATION THROUGH ROBOTICS

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Abstract: This manuscript studies the parameters that describe the risks of implementing in libraries a robot that takes over the tasks of human resources, being able to take over the requests for customer consultation, scanning books and cards, checking the customer's eligibility, the process of returning a book or extending a return deadline. This mechatronic system is composed of an articulated arm to execute the pick and place application, a filing compartment, a platform using Light Detection and Ranging (LIDAR) technology for shelf navigation, a scanner with radio frequency identification (RFID) technology, and other data acquisition components. The objective of this study is to support the improvement of the reliability of this technology by analyzing the risks involved.

Keywords: Risk management, Library robots, Technological innovation.

1. Introduction

Technological innovation is the main driver of economic progress and sustainable development in an era of rapid change and intense competition. However, the process of technological innovation is accompanied by multiple uncertainties and risks that can influence the success of innovative projects and initiatives [1]. Risk management is an essential process within innovation strategies, ensuring that risks are identified, assessed and managed to maximize the chances of success and minimize the likelihood or potential impact of potential problems.

Effective risk management enables organizations to anticipate and address problems before they become critical. By applying appropriate techniques and tools, organizations can reduce uncertainty and improve the chances of success of their innovative projects. The process of risk management involves identifying risks, assessing their likelihood and impact, developing and implementing risk management strategies, and continuously monitoring risks and control measures. Identifying risks involves detecting possible sources of problems and analyzing their potential impact on the

project [2]. Risk assessment is the estimation of the likelihood of occurrence and the severity of impact of the identified risks, and risk management is the development of strategies to avoid, transfer, reduce or accept those risks. Monitoring and review are necessary to ensure adaptability to changing contexts and project developments.

The risk associated with the technologization process can be considered mainly speculative or opportunity risk, as it involves significant investment in existing infrastructure, such as library modernization. However, the implementation of mechatronic systems brings with it additional risks that go beyond the speculative. These risks include potential hazard issues, such as technical failures or operating errors that may affect the functionality of the systems, as well as control risks, related to proper management and monitoring [3]. Thus, in addition to the risks related to investment opportunities, measures to prevent and manage the technical and operational risks associated with new technologies should also be considered. The study will focus on the specific risks associated with deploying a robot in libraries, equipped with an articulated arm for lifting and placing operations, an archiving compartment,

a platform equipped with LIDAR technology for browsing shelves, a scanner with RFID technology, and other data collection components.

The process of identification and risk assessment was assisted by engineers working in the field of scientific research.

2. Risk Identification

Specific risks have been identified in the process of library technologization through robotics (Table 1). These are generated by the counteraction of each subsystem of the robot and by the decision-making processes, characterized by the software component.

Tab 1. Risk classification

Risk symbol	Risk area	Category	Subcategory	Description	Type of risk
R1	Customer interaction risks	Request handling	Miscommunication	Robots may misunderstand or fail to accurately process customer requests due to speech recognition errors or language barriers.	Control
R2			User interface issues	Difficulty in using the robot interface, leading to customer frustration.	Control
R3			Accessibility challenges	Inability to cater to customers with disabilities or special needs effectively.	Control
R4	Client-robot workflow	Book return processing	Misidentification	Errors in identifying returned books, leading to incorrect updates in the system.	Hazard
R5			System errors	Glitches or downtime in the system that handles return transactions.	Hazard
R6		Deadline extension	Incorrect processing	Errors in extending return deadlines, which can lead to penalties or availability problems.	Hazard
R7			Policy adherence	Ensuring robots follow library policies and handle exceptions correctly.	Control
R8	Shelf navigation risks	Navigation and movement	Collision risks	Robots colliding with shelves, furniture, or people due to navigation errors.	Hazard
R9			Pathfinding errors	Inability to accurately navigate the library layout, leading to inefficiencies.	Hazard
R10			Environmental adaptation	Challenges in adapting to changes in the library environment, such as temporary obstacles.	Hazard
R11	Lifting and placing books risks	Handling books	Damage to books	Risk of robots damaging books during lifting or placing due to inappropriate handling or malfunctions.	Hazard
R12			Weight limitations	Inability to handle books that are too heavy or bulky for the robot's design.	Control
R13	Scanning books risks	Scanning accuracy	Barcode/Tag reading errors	Errors in reading barcodes or RFID tags, leading to incorrect inventory updates.	Hazard

R14			Technology compatibility	Compatibility issues with existing scanning technology or formats used by the library.	Hazard
R15	Technical issues	Software and hardware faults	Hardware issues	Physical components breaking down, requiring repairs or replacements.	Hazard
R16			Software errors	Software errors that cause robots to behave unpredictably or fail to complete tasks.	Hazard
R17	Security and privacy	Data protection and information security	Data breaches	Unauthorized access to sensitive customer or library data.	Hazard
R18			Privacy concerns	Ensuring customer interactions and data are handled with confidentiality and comply with privacy laws.	Control
R19	Maintenance and support	Ongoing maintenance and technical support	Maintenance downtime	Time required for regular maintenance affecting the availability of robots.	Hazard
R20			Technical support	Adequate support to troubleshoot and resolve issues promptly.	Speculative
R21	Human factors	Adaptation	Staff training	Ensuring library staff are adequately trained to work with and support robotic systems.	Speculative
R22			Customer adaptation	Customers' acceptance and adaptation to interacting with robots.	Speculative
R23			Staff resistance	Resistance or reluctance from staff to adapt to new technology.	Control

A systematic risk assessment of the risks associated with the integration and use of robots in a library environment has been carried out, providing a categorization according to risk area, specific category and type of risk involved. This assessment is essential for the identification, analysis and effective management of potential problems that may arise in the context of operating robots in libraries, given the complexity of human-machine interactions and the impact on services and user experience.

First, the risks related to patron interaction are categorized into three further sub-categories, including communication issues, interface usability difficulties and accessibility challenges. The communication risk (R1) is associated with possible speech recognition errors and language barriers that may prevent correct understanding of customer requests. These errors are attributed to the inaccuracy of speech recognition technology and language diversity, and can negatively influence service quality and user satisfaction. The risk related to interface usability difficulties (R2) refers to problems encountered by customers in interacting with the robot interfaces, which can lead to frustration and affect the experience, decreasing satisfaction. In addition, accessibility risks

(R3) involve difficulties in adapting the technology to meet the needs of people with disabilities, which may limit the efficiency and inclusiveness of the services offered.

In the second category, risks associated with processing book returns are explored. These risks include identification errors (R4), in which robots may have difficulty correctly recognizing returned books, which can lead to erroneous inventory system updates and operational problems. Risks of system problems (R5) are related to potential technical malfunctions that may affect the operation of the card return system [1], including software bugs and service interruptions. Risks of incorrect processing of return deadlines (R6) relate to errors in the handling of deadline extensions, which may lead to penalties and card availability problems.

The third category deals with risks related to browsing and shelf movement. Collision risks (R8) are associated with possible accidents in which robots may hit shelves, furniture or people due to navigation errors, which can cause physical damage and disruption to workflow. The risks of route-finding errors (R9) involve difficulties in determining and following appropriate routes in the library, which can lead to inefficiencies and

delays. In addition, environmental adaptation risks (R10) refer to the challenges faced by robots in the face of temporary changes in the environment, such as unexpected obstacles, which may affect their ability to operate efficiently.

Risks related to card handling and scanning are also of crucial importance. Risks of damage to books (R11) refer to the potential destruction of books due to mishandling or technical faults. Risks of weight limitations (R12) indicate the problems encountered when robots are unable to handle books that are too heavy or bulky, exceeding their technical specifications. Risks of barcode or RFID tag reading errors (R13) can cause incorrect inventory updates, negatively influencing resource management and tracking. Technological compatibility issues (R14) with existing scanning technologies may also create difficulties in effectively integrating the robotic scanning system with existing library infrastructure.

In terms of technical and maintenance issues, risks include hardware malfunctions (R15) and software bugs (R16), which may affect the performance and reliability of the robots. Hardware failures may lead to the need for frequent repairs and software errors may cause unpredictable behavior, affecting operational efficiency. Data protection and privacy risks (R17 and R18) are essential to ensure the security of customers' personal information and compliance with privacy legislation. These risks require rigorous security measures to prevent unauthorized access and protect sensitive data.

Finally, speculative risks are included to assess issues related to staff training (R21) and customer acceptance (R22). Risks related to the need for adequate staff training are important to ensure that employees are sufficiently trained to manage and maintain robots [4]. Staff resilience risks (R23) to new technologies are control risks that involve managing change and ensuring effective transition. Customer acceptance and adaptation to interacting with robots are also uncertainties that may influence the success of the technological implementation.

In the presented risk analysis, risks with a negative and easily quantifiable impact have been categorized as "hazard" risks. These risks are characterized by a negative and easily quantifiable impact with the potential to significantly affect the operational functioning of the library [5]. These risks are related to problems that can be objectively measured and evaluated, such as errors in the identification of returned books, system failures, or collisions caused by improper robot navigation. Hazard risks are direct and immediate and their impact can be quantified by specific performance, operational or financial indicators [6].

Control risks are associated with the project management side and are less direct in terms of their negative impact and very difficult to quantify. These risks are related to management issues that can be regulated and monitored by control measures [7].

Speculative' risks are deliberately assumed risks that involve favorable and desired scenarios with the aim of achieving future benefits [8]. These risks relate to issues such as investments in staff training and customer acceptance of new technologies. Speculative risks involve uncertainty and are based on optimistic scenarios that, if they materialize, can lead to significant and positive outcomes. Investments in training staff to use robots effectively and efforts to integrate robotic technologies into the user experience are considered speculative risks. Managing them involves allocating resources and developing strategies that maximize the chances of success and minimize the risks associated with possible adverse scenarios.

3. Risk Evaluation

Risk evaluation involves assessing the identified risks in terms of their probability and potential impact on the library's operations. This helps prioritize which risks need more immediate or substantial mitigation efforts. The risks were given a whole number score, from 1 to 10, for both the likelihood and the impact of the risk materializing (Table 2). The risk factor was determined as:

$$R_i = P \times I \quad (1)$$

Tab 2. Risk evaluation

Risk symbol	Probability	Impact	Risk index
R1	6	5	30
R2	2	2	4
R3	2	7	14
R4	2	2	4
R5	2	3	6
R6	3	7	21
R7	2	4	8
R8	4	4	16
R9	5	6	30
R10	8	4	32
R11	6	5	30
R12	1	6	6
R13	4	4	16
R14	4	6	24
R15	4	6	24
R16	7	7	49
R17	6	8	48
R18	3	5	15
R19	4	2	8
R20	7	5	35
R21	6	9	54
R22	6	6	36
R23	8	5	40

The prioritization of risks based on their importance and risk index starts with speculative risks, which are deemed the most important [9]. In this category, risks R21, R22, and R20 lead with risk indices of 54, 36, and 35, respectively. Following these, the next highest risks, ordered in descending order by risk index, are R16 with 49, R17 with 48, and R23, another speculative risk, with 40. These are followed by R10 with 32 and then three risks with an index of 30: R9, R1, and R11. This approach ensures that speculative risks are managed first, followed by other risks according to their severity.

4. Risk Management Strategy

Risk mapping is a specific tool in risk management, used to assess and prioritize risks according to their likelihood of occurrence and the impact they could have on a project or organization. It categorizes risks in a visual framework (Figure 1) that helps determine risk management strategies [9]. The abscissa, the horizontal axis, represents the probability of risk occurrence, ranging from low probability on the left to high probability on the right. The ordinate, the vertical axis, indicates the impact of risks, ranging from low impact at the bottom to high impact at the top.

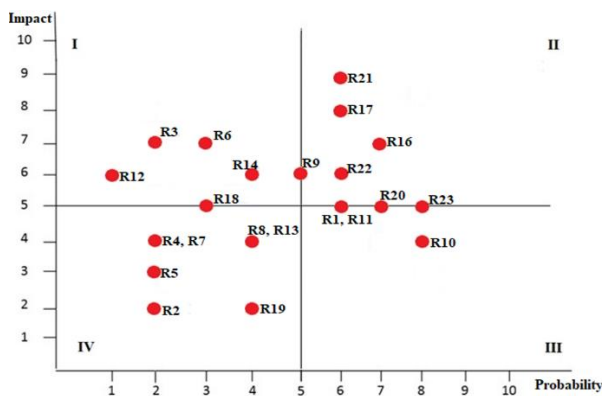


Fig. 1. Risk Matrix

The matrix is divided into four distinct quadrants, each suggesting a different risk management strategy (Tab. 3).

The first quadrant, known as quadrant I, includes risks with a low probability of occurrence but high impact if they materialize. For risks in this quadrant, the recommended strategy is risk transfer. This involves moving the risk to a third party, through measures such as insurance or subcontracting, so that the impact is managed by someone else. For example, risks related to unforeseeable events, which have a significant impact, are better managed by transferring responsibility. This quadrant includes risks R3, R6, R9, R12, R14 and R18 at its boundaries.

Quadrant II contains risks with a high probability of occurrence and high impact. The approach strategy here is risk termination. This implies the complete

elimination of the risks by ceasing activities or projects that present a significant risk. However, it is important to note that speculative risks, which have the potential for significant gains, are not excluded by the termination strategy, as they are deliberately taken for opportunities, even if they involve high risks. Thus, for speculative risks, termination does not apply, as they are accepted for the possible advantages they offer. In this quadrant are risks R16, R17, R21 and R22, with risks R1, R9, R11, R20 and R23 at its boundaries.

Quadrant III contains risks with a low probability and low impact. For these risks the recommended strategy is to treat. This involves the implementation of preventive and control measures to reduce both the likelihood of occurrence and the potential impact of the risks. Measures may include internal policies and processes designed to minimize the effects of minor risks so that they do not significantly affect the project or organization. Here is risk R10, bordering risks R1, R11, R20 and R23.

Finally, quadrant IV refers to risks with low probability and low impact. Here the appropriate strategy is risk tolerance. This involves accepting risks as they are, without investing additional resources in their management, as the impacts are considered minimal and acceptable. Risks in this quadrant are those that do not warrant additional control or prevention measures due to their low impact on the project or organization. Risks R2, R4, R5, R7, R7, R8, R13 and R19 are found here, with R18 at the border.

Tab 3. General risk management strategy

Risk general strategy	Risk symbol
Transfer	R3; R6; R8; R9; R12; R14; R15; R18
Terminate	R1; R8; R11; R16; R17; R20; R21; R22; R23
Treat	R1; R11; R20; R23
Tolerate	R2; R4; R5; R7; R8; R10; R13; R18; R19

The risks at the boundaries of the quadrants will be dealt with according to the context and the capabilities of the implementation team. By using the risk matrix, organizations can effectively identify and rank risks, enabling them to develop appropriate action plans and allocate resources to manage risks according to their importance and severity [10].

5. Conclusions

Technological innovation, particularly when it involves sophisticated and intricate systems, inherently comes with increased risks and challenges. The implementation of robotics in libraries, as analyzed in this study, exemplifies how the complexity of advanced technologies magnifies the scope of potential risks. As these robotic systems integrate more sophisticated

components—such as articulated arms, LIDAR navigation, RFID scanners, and various data acquisition elements—the risk landscape becomes more intricate and multifaceted.

The study highlights that while technological advancements promise significant improvements in efficiency and service quality, they also introduce new layers of risk. These risks range from technical failures and system errors to issues with user interaction and data security. The complex interplay of these factors means that the potential for operational disruptions, service inefficiencies, and security breaches is higher compared to simpler technological implementations.

The detailed risk assessment and categorization provided in this study offer a structured approach to identifying, evaluating, and mitigating these risks. By focusing on the most critical risks—those with high impact and likelihood—libraries can prioritize their resources and strategies to address the most pressing issues. This includes implementing robust technical solutions, ensuring comprehensive staff training, and maintaining strict data security protocols.

In conclusion, while the integration of robotic systems in libraries holds substantial promise for enhancing operational efficiency and user experience, it also requires careful consideration and management of associated risks. The complexity of these technologies necessitates a proactive and well-defined risk management strategy to ensure successful implementation and sustained operational reliability. By addressing the identified risks and following the recommended management strategies, libraries can better navigate the challenges of technological innovation and realize the full potential of their robotic systems.

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7. References

- [1] Broad J.: “Chapter 3 - Integrated Organization-Wide Risk Management”, Risk Management Framework, Broad J., Ed., Boston: Syngress, 2013, pp. 23–32. doi: 10.1016/B978-1-59749-995-8.00003-X.
- [2] Micán C., Fernandes G., Araújo M., Ares E.: “Operational risk categorization in project-based organizations: A theoretical perspective from a project portfolio risk lens”, *Procedia Manufacturing*, vol. 41, pp. 771–778, Jan. 2019, doi: 10.1016/j.promfg.2019.09.069.
- [3] Kramarz K., Korpysa J.: “The evolution of the concept of risk management in IT+ organizations”, *Procedia Computer Science*, vol. 225, pp. 4843–4849, Jan. 2023, doi: 10.1016/j.procs.2023.10.484.
- [4] Becker K., Smidt M.: “A risk perspective on human resource management: A review and directions for future research”, *Human Resource Management Review*, vol. 26, no. 2, pp. 149–165, Jun. 2016, doi: 10.1016/j.hrmr.2015.12.001.
- [5] Liu B., Han X., Qin L., Xu W., and Fan J.: “Multi-hazard risk mapping for coupling of natural and technological hazards”, *Geomatics, Natural Hazards and Risk*, vol. 12, no. 1, pp. 2544–2560, Jan. 2021, doi: 10.1080/19475705.2021.1969451.
- [6] Yin J., Yin Z., Xu S., Wang J., Zhong H.: “Progress in Multi-hazard Comprehensive Risk Assessment”, 4th Annual Meeting of Risk-Analysis-Council-of-China-Association-for-Disaster-Prevention, vol. 13, p. 786, 2010.
- [7] Mitra S., Karathanasopoulos A., Sermpinis G., Dunis C., Hood J.: “Operational risk: Emerging markets, sectors and measurement”, *European Journal of Operational Research*, vol. 241, no. 1, pp. 122–132, Feb. 2015, doi: 10.1016/j.ejor.2014.08.021.
- [8] Flood R.P., Marion N.P.: “Self-fulfilling risk predictions: an application to speculative attacks”, *Journal of International Economics*, vol. 50, no. 1, pp. 245–268, Feb. 2000, doi: 10.1016/S0022-1996(98)00039-7.
- [9] Lengyel D.M., Mazzuchi T.A., Vesely W.E.: “Establishing risk matrix standard criteria for use in the continuous risk management process”, *Journal of Space Safety Engineering*, vol. 10, no. 3, pp. 276–283, Sep. 2023, doi: 10.1016/j.jsse.2023.05.001.
- [10] Sutherland H., Recchia G., Dryhurst S., Freeman A.L.J.: “How People Understand Risk Matrices, and How Matrix Design Can Improve their Use: Findings from Randomized Controlled Studies”, *Risk Analysis*, vol. 42, no. 5, pp. 1023–1041, May 2022, doi: 10.1111/risa.13822.