Pharmacy Automation and Robotics

Hossein I.,[1] Maryam A.[2], F.J. Yelwa [3]

[1] Department of Clinical Pharmacy and Pharmacy Practice, Faculty of Pharmaceutical Sciences, Usmanu Danfodio University, Sokoto,

[2] Usmanu Danfodio University Teaching Hospital, Sokoto, Sokoto State,

[3] Department of Agricultural Extension and Rural Development, Faculty of Agriculture, Usmanu Danfodio University, Sokoto

DOI: https://doi.org/10.51583/IJLTEMAS.2025.1407000014

Received: 06 July 2025; Accepted: 10 July 2025; Published: 31 July 2025

Abstract: The pharmaceutical landscape is undergoing a transformative revolution through the integration of automation and robotics, which offer significant improvements in precision, efficiency, and patient care. This research aims to highlight the transformative impact of these technologies and guide key stakeholders, including researchers, pharmacists, industry professionals, and policymakers, toward informed investment and effective implementation strategies. A descriptive review methodology was employed to explore the historical evolution, classifications, and practical applications of robotic systems, with a focus on Cartesian, SCARA, and articulated robots. The study draws on current literature, regulatory frameworks, and case-based evidence to analyze their adoption and operational dynamics in pharmaceutical premises. Despite challenges such as high initial investment and workforce displacement, the overall findings reflect a net positive contribution to pharmaceutical quality, safety, and global competitiveness. The paper concludes by advocating for strategic adoption, continuous innovation, and regulatory alignment to unlock the full potential of these technologies in modern pharmaceutical practice.

Keywords: Automation, robotics, technologies, pharmaceutical advancement, industrial robots

I. Introduction

Advancements in healthcare are evolving at an unprecedented pace, with automation and robotics systems now assuming a vital role within pharmaceutical science and clinical practice. These technologies are revolutionizing how tasks are performed, enhancing accuracy, operational efficiency, product consistency, and ultimately, patient outcomes. The integration of automation and robotics into pharmacy workflows represents not just technological evolution but also a strategic shift in how pharmaceutical care and production are delivered globally [1].

Automation, in the pharmaceutical context, refers to the application of mechanical systems, software platforms, and computerized technologies to perform repetitive or complex tasks with minimal human intervention. It encompasses a range of solutions, including automated dispensing cabinets, labeling machines, sorting systems, and robotic arms, all designed to increase precision, reduce errors, and optimize workflows [1, 3].

Robotics is the science and branch of technology of robots that deals with the design, construction, and operation of programmable machines (robots) that can assist or replace humans in various tasks. The Robotics Institute of America defines a robot as a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. In pharmaceutical environments, robots are utilized in drug compounding, sterile manufacturing, lab sample handling, and even in outpatient care through robotic dispensing kiosks [2, 4].

While automation and robotics are often discussed interchangeably, it is important to distinguish between the two. Automation refers broadly to mechanized processes and systems, whereas robotics specifically involves the use of programmable machines capable of adaptive, task-specific functionality.

This paper provides a comprehensive overview of automation and robotics in the pharmaceutical industry, discussing their types, applications, benefits, challenges, future directions, and key considerations before investing in pharmaceutical automation and robotics. This study aims to highlight the transformative impact of these technologies and guide stakeholders (researchers, pharmacists, industry professionals, and policymakers) toward informed investment and implementation strategies. As pharmacy practice becomes increasingly data-driven and technology-enabled, embracing automation and robotics is no longer optional but essential for staying competitive in the international pharmaceutical landscape.

Historical Evolution

The concept of automation and robots can be traced back to medieval times, when water-powered clocks were created. In the 18th century, miniature automata became popular as toys for the very rich. They were made to look like humans or small animals that can turn their head and play an instrument like a drum with their hands. Jump forward another century and you'll find the first inventions that involve automation to make work easier, such as Joseph-Marie Jacquard's machine that printed designs onto cloth

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

or Zadoc Dederick's 'Steam Man', which pulled a cart. In 1818, Mary Shelly wrote Frankenstein, a story about the construction of a human-like creature that could function like a machine and was held together by nuts and bolts. In 1920, the word 'robot' was first introduced into our vocabulary by Czech playwright Karel Čapek in his play called Rossum's Universal Robots. It wasn't until the 1940s that the modern-day robot was born, with the arrival of computers [5, 6].

Looking back, we have come a long way, and it is surprising to see just how early humans decided to create things that could function on their own. Self-driving cars are coming closer to being a reality, and super-accurate robotic tools are already being used in hospitals around the world. It is going to be interesting to see what is added to the timeline in the coming years.

Types of Robots

According to Mukherjee et al., (2021), the most commonly used industrial robots in pharmaceutical manufacturing are of three types: Cartesian, SCARA, and articulated.

Cartesian robots: Cartesian robots are linear slides with motorized horizontal movement, a quill for the end-effector, and a fourth axis for rotation. They are low-cost but have limited motion range, making them often used in automation subsystems or machines for single purposes.

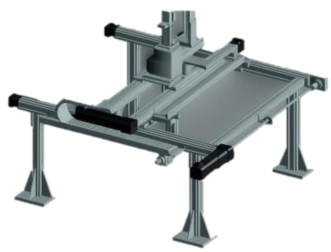

Fig. 1: credited to Johnson. A., & Venkatesh. M. (2017).

SCARA robots: SCARA, or Selective Compliance Articulated Robot Arm, allows arm segments to move freely in a single geometrical plane, typically having four axes, but also three- and five-axis robots are found. SCARA robots have small footprints and are lightweight; thus, they make them ideal for applications in crowded spaces. SCARA robots are capable of speedy cycle times.

Fig. 2: credited to Johnson. A., & Venkatesh. M. (2017).

Articulated robots: Articulated robots have more joints, horizontal and vertical, and a spherical work envelope compared to the SCARAs, giving them increased freedom of movement. This flexibility allows them to perform tasks similar to human arm and hand tasks. The most common articulated robots have six axes. This allows the robot to perform many other tasks that would otherwise call for the dexterity of a human operator.

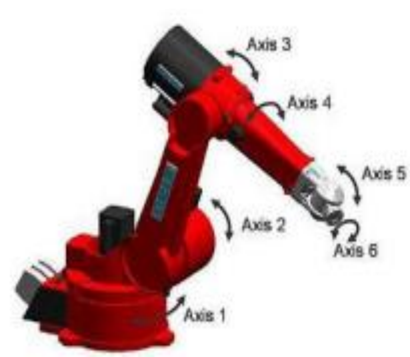

Fig. 3: credited to Johnson. A., & Venkatesh. M. (2017).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

According to Su, X., et al., (2022), pharmaceutical applications of the robots are not limited to:

Robot Type	Applications in the Pharmaceutical Industry
Cartesian	High-precision pick and place for blister packs, vials, and tablets Labelling and packaging of products Automated dispensing in pharmacy automation systems Syringe filling and inspection Sealing and capping operations
SCARA	Assembly of medical devices (e.g, syringes, auto-injectors) Tablet inspection and sorting Laboratory sample transfer High-speed bottling operation Vial and ampoule handling Screwing caps onto containers
Articulated	Sterile drug handling in aseptic environments Automated cleanroom operations Heavy-duty material handling (e.g, loading, unloading) Complex packaging tasks Automated compounding of medications Surgical equipment handling Precision inspection and sorting in quality control assessment

Applications in Pharmaceutical Industry

In the world of pharmaceuticals, there is an important role for robotics to play in the complicated processes of research and development, production, and packaging. Justification for robots ranges from improved worker safety to improved quality. Speeding up the drug discovery process is another benefit of robotics. A number of robot manufacturers have products specifically designed for this industry.

Robotics in sterile manufacturing: Robust aseptic processing involves handling sterilized components and ingredients without recontamination, requiring active process risk management. A sterility assurance strategy focuses on eliminating contamination and making the process seamless. Robotics can overcome human removal challenges and prevent particle contamination in traditional manufacturing. Robotic aseptic processing can be organized into modular process blocks, providing Grade A air and a flexible end-to-end process. Scaling out clinical batches to robotic process lines allows faster technology transfer for worldwide launch plans [2]

Research and development (R&D): Robots are essential in drug development, particularly in high-throughput screening (HTS), where millions of compounds are tested to determine potential drugs. Robots significantly speed up this process and perform repetitive tasks [2,4,8].

Control Systems: Control Systems. Most robots have onboard controllers that communicate with other machines' Programmable Logic Controllers (PLCs) or with personal computers (PCs) networked to the line. Robot controller is an industrial VERSA-Module Euro Card (VME) bus controller that connects to PCs for networking and for graphical user interfaces [2,8].

Laboratory robotics: Laboratory robotics enables human talents to focus on sample selection, submission, and data scrutiny, leading to better data and reduced costs. This technology is increasingly used in pharmaceutical development to increase productivity, decrease drug development time, and reduce costs. Common laboratory robot geometries include Cartesian (three mutually perpendicular axes), cylindrical (parallel action arm pivoted about a central point), and anthropomorphic (multijointed, human-like) configurations [2,4,8].

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

Vision systems: A vision system enhances text and graphics accuracy in pharmaceutical and medical packaging, with a robot offering speed, inspection, and insertion in less than two minutes. The same inspection performed by one operator and checked by a second operator could take from 30 minutes to an hour [2,8].

Sterilization and clean rooms: Robotics can be used in clean room environments to protect the sterile environment from contamination. These robots have features like low-flake coatings, stainless steel fasteners, and enclosed cables. They reduce costs by automating inspection, picking, and unloading of process tools. Benefits include reduced scrap, contamination, consumable use, and space usage. Mini-environments allow for relaxed cleanliness [2,8].

Flexible feeding: Robots are also better than hard automation at flexible feeding, a task that involves handling multiple types of products or packages whose orientation always varies. Traditionally, packaging lines have used high-speed, automated bowl feeders that vibrate parts and feed them to fillers, labelers, or product-transfer mechanisms. Bowl feeders, however, can't always handle a variety of products at once, and their vibration can damage fragile parts [2,8].

Benefits of Industrial Robots

Speed: Robots work efficiently without wasting movement or time. Without breaks or hesitation, robots can increase productivity by enhancing output [1,3,8].

Flexibility: Robots can be easily reprogrammed based on packaging applications. End-of-Arm Tooling (EOAT) developments and vision technology have expanded the application-specific abilities of packaging robots [2].

Tirelessness: A robot can perform a 96-man-hour project in 10 hours with more consistency and higher quality results [2,3].

Accuracy: Robotic systems are more accurate and consistent than their human counterparts [1,8].

Reliability: Robots work seamlessly and consistently to achieve uniform output always [2,3].

Increase quality and quantity: Robots can dramatically improve product quality through precision, high repeatability, and being microbe-free every time. With robots, an increase in production output can be achieved through accuracy, speed, and reliability. This level of consistency can be hard to achieve in any other way [2,3,4].

Savings: Automated packaging minimizes costs across the board. Not only has output increased, but robots are tireless. The results of introducing industrial robots will solely guarantee higher profitability levels with a lower value per product by increasing the potency of your method, reducing the resources and time needed to finish it, and simultaneously achieving higher-quality merchandise [3,4].

Increase Efficiency: When it comes to pharmaceutical production, people are not as efficient as robots, especially when they are wearing a protective suit. Industrial robots will complete tasks more quickly and efficiently than humans, as they're designed to perform them with higher accuracy [1,2,3].

Safety: Robots increase workplace safety. Workers are moved to supervisory roles, so they no longer have to perform dangerous applications in hazardous settings [1,2,4].

Reduced chances of contamination: Removing people from the screening process reduces the potential for contamination and the potential for dropped samples when handling them in laboratories. Robotics performs these tasks much faster with more precision and accuracy [2,3,8].

Can work continuously in any environment: Another advantage of using robots is that they are resistant to many hazardous environments that would be dangerous to humans. A robot can operate with pinpoint accuracy 24 hours a day, seven days a week [3,4].

Challenges of Industrial Robots

Dangers and fears: Although current robots are not believed to have developed to the stage where they pose any threat or danger to society, fears and concerns about robots have been repeatedly expressed in a wide range of books and films. The principal theme is that robots' intelligence and ability to act could exceed that of humans, that they could develop a conscience and a motivation to take over or destroy the human race [2,3].

Expense: The initial investment in robots is significant, especially when business owners are limiting their purchases to new robotic equipment. The cost of automation should be calculated in light of a business's greater financial budget. Regular maintenance needs can have a financial toll as well [3,4].

Expertise: Employees will require training in programming and interacting with the new robotic equipment. This normally takes time and financial output [3,4].

Safety: Robots may protect workers from some hazards, but in the meantime, their very presence can create other safety problems. These new dangers must be considered [1,2,3].

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

Transferring of samples: When samples must be transferred between different bays for different unit operations, this presents a challenge (for analysis, dispensing, processing, etc.) [2].

Job-related challenges: Some challenges are related to job loss, as the Organization for Economic Cooperation and Development (OECD) estimated in 2019 that 35% of jobs may be seriously affected by automation, and 14% of current jobs may no longer be available due to automation. It is estimated that the jobs of low-skilled workers may be affected [2].

Considerations

Hole, G., et al., (2021), Munjaji, S. K., et al., (2023), & Thomsen, C. (2013) explained that before investing in pharmacy automation and robotics, these six steps are to be considered.

Know your objective: Decide and rank-order your needs, such as error reduction, speed increase, increased efficiency, standardization, removal of manual steps, etc. Without laying down your objectives, you can achieve anything reasonable.

Know your budget range: It is nice to dream about the shiny new contraption or the sweeping software platform, but you should know what you can put aside. One important decision to make is lease vs. buy. Your accountant should be consulted to see which strategy is best for your cash flow.

Identify your technology team: To increase success, assign capable staff members as co-planners, implementers, and trainers, with a lead person as a "superuser" who can serve as the head trainer, troubleshooter, and maintenance point. A superuser should be interested in new technology, engaged daily, and consult a trusted robot company for a specific robot type and activity.

Know your automation and robotic partner: Go beyond just the purchase or rental price and have pointed conversations about the impact of any technology, including maintenance costs, service records, training, re-modelling costs, inventory impacts, etc. as their track record for delivering on their promises.

Do your homework: Ask for pharmacy premises/pharmaceutical industries that are currently using the technology you are about to step into. See the technology firsthand, either in person or virtually, to know the type and how big it is, so that a convenient environment will be provided for the technology to work efficiently. In the past, a site visit or trade show may have been the only way to see a new technology. Today, you may get the same benefits with a live streaming video demonstration or online tools.

Set your timeline: This may be impacted by the above factors.

II. Future Trends

The premise of automation and robots in the pharmacy and pharmaceutical industry holds promising prospects for transformative change. As the need for speed, precision, safety, and flexibility continues to grow, so too does the role of automation technologies. The pharmaceutical sector has a wide range of vision applications, making it one of the most fertile grounds for the growth of robotic systems. The full potential of material handling robots, intelligent packaging systems, and autonomous laboratory operations is only beginning to emerge [8,9].

In the near future, key advancements are expected to reshape the landscape of pharmaceutical automation and robotics: Artificial Intelligence (AI) and Machine Learning (ML) e.g, AI-enabled robots can make real-time adjustments during aseptic manufacturing or anticipate maintenance needs, reducing downtime and improving productivity; Collaborative Robots (Cobots) such as cobot for high-precision and repetitive vial filling; Cloud Robotics and Internet of Thing (IoT) Integration e.g, IoT sensors embedded in robots that collect critical data such as temperature, humidity, or vibration to ensure that processes comply with strict pharmaceutical standards and regulations; Digital Simulation Models to reduce implementation errors, lowers cost, and accelerates technology transfer from R&D to production; Human-Robot Interaction and Natural Language Processing (NLP) that will facilitate interaction with human operators using voice recognition, gesture controls, and NLP; Smart Vision and AI-Based Inspection Systems that can detect microscopic defects, verify labeling accuracy, and ensure dosage uniformity at speeds far beyond human capability, and Modular and Mobile Robotics such as Automated Guided Vehicles (AGVs) that can deployed for transporting raw materials, intermediate compounds, and finished goods autonomously within pharmaceutical plants [8, 11, 16, 20].

With the innovations, the pharmaceutical industries and pharmacy premises are set to witness unprecedented advancements in efficiency, safety, and patient-centered care. Forward-looking investment in these technologies is no longer optional; it is a strategic imperative that will define the next era of pharmaceutical innovation. According to Thomsen, C. (2013), find a way to invest in technology and automation, the Return on Investment (ROI) exists when used appropriately [9].

III. Conclusion

Embracing automation and robotics in pharmaceuticals heralds a new era of precision, efficiency, and improved overall patient care. From historical clockwork marvels to today's sophisticated robots, the journey reflects a relentless pursuit of innovation.

The diverse applications, spanning sterile manufacturing, research, control systems, and beyond, underscore their pivotal role in shaping the pharmaceutical landscape. Despite concerns about job displacement and initial costs, the undeniable advantages, such

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

as speed, flexibility, accuracy, and safety enhancements, emphasize the transformative impact on productivity and product quality.

For potential investors, a roadmap is laid out, emphasizing clear objectives, budget awareness, adept technology teams, and informed partnerships. Looking ahead, the article envisions a future where automation and robotics propel pharmaceuticals into realms of unprecedented growth and sophistication. The resounding advice resonates: invest wisely, and the Return on Investment (ROI) in this automation-driven future will be substantial.

IV. Acknowledgement

The authors gratefully acknowledge the invaluable support received during this research. Support toward the publication process is also duly recognized and appreciated. The contributions of all those who facilitated the successful completion of this study are sincerely acknowledged.

References

1. Munjaji, S. K., Santosh, K. S., Ameen, M., & Ahmad, J. (2023). Pioneering pharmacy practice: The integration of automation and robotics for enhanced patient care. Journal of Emerging Technologies and Innovative Research (JETIR),10(9), 872-878.
2. Kundap S, Karpe M, & Kadam V. (2021). Robotics in Pharmaceutical Industry. Indo American Journal of Pharmaceutical Research, 10(11). www.iajpr.comwww.iajpr.com
3. Teja, L. T., Keerthi, P., Datta, D., & Babu, N. M. (2014). Recent trends in the usage of robotics in pharmacy. Indian Journal of Research in Pharmacy and Biotechnology, 2(1), 1038.
4. Nandi1, S., & Das, S. (2021). Robotics in the pharmaceutical industry. International Journal of Pharmacy and Pharmaceutical Research,21(2)
5. Fron, C., & Korn, O. (2019). A Short History of the Perception of Robots and Automata from Antiquity to A Short History of the Perception of Robots and Automata from Antiquity to Modern Times. July, 0–12. https://doi.org/10.1007/978-3-030-17107-0
6. Staccioli, J., & Virgillito, M. E. (2021). Back to the past : the historical roots of labor-saving automation. In Eurasian Business Review (Vol. 11, Issue 1). Springer International Publishing. https://doi.org/10.1007/s40821-020-00179-1
7. Mukherjee, S., Falguni Patra, F., & Mahanti, B. (2021). Robotics in pharmaceutical manufacturing. World Journal of Pharmaceutical and Medical Research,7(6)
8. Yearimani, S., Bhilegaonkar, S., Gawade, H., Desai, Y., & Sheikh, M. (2022). Robotics to Grow Sharply in Pharmaceutical Industry. Advances in Robotics & Automation, 11(6), 11–13. https://doi.org/10.37421/2168-9695.2022.11.218
9. Thomsen, C. (2013). Pharmacy automation in retail pharmacies: Assessing the right reasons, the right time, and the right extent to automate. The Thomsen Group Inc.
10. Shivaji1, B.S., Mushtaqahmed, J. A., & Suresh, G. U. (2013). Medical robotics and automation. International Journal of Mechanical Engineering and Robotics Research,2(4)
11. Qureshi, M. O., & Sajjad, R. (2017). A Study of Integration of Robotics in the Hospitality Sector and Its Emulation in the Pharmaceutical Sector. Health Science Journal, 11(1), 1–6. https://doi.org/10.21767/1791-809x.1000483.
12. Deepa1, N., Devadharshini, S., Iswarya, V., Parameswari, B., & Ramyadasan, S. (2023). Pharmarobotic automation system for pharmacy. International Journal of Research Publication and Reviews,4(4), 1888-1893. www.ijrpr.com.
13. Johnson. A., & Venkatesh. M. (2017). Design and Fabrication of Pick and Place Robotic Arm Controlled by Android Device. International Journal of Engineering and Management Research 7(1), 157-162. www.ijemr.net.
14. Lin, A., Gamble, J., Gabriel, M., & Hong, T. (2024). Evaluating the impact of an automated drug retrieval cabinet and robotic dispensing system in a large hospital central pharmacy. American journal of health-system pharmacy: AJHP: official journal of the American Society of Health-System Pharmacists. https://doi.org/10.1093/ajhp/zxae225.
15. Bagattini, Â., Borges, J., Riera, R., & De Carvalho, D. (2022). Automation of a tertiary hospital pharmacy drug dispensing system in a lower-middle-income country: A case study and preliminary results. Exploratory Research in Clinical and Social Pharmacy, 6. https://doi.org/10.1016/j.rcsop.2022.100151.
16. Tanzini, A., Ruggeri, M., Bianchi, E., Valentino, C., Vigani, B., Ferrari, F., Rossi, S., Giberti, H., & Sandri, G. (2023). Robotics and Aseptic Processing in View of Regulatory Requirements. Pharmaceutics, 15. https://doi.org/10.3390/pharmaceutics15061581.
17. Hole, G., Hole, A., & McFalone-Shaw, I. (2021). Digitalization in pharmaceutical industry: What to focus on under the digital implementation process? International Journal of Pharmaceutics: X, 3. https://doi.org/10.1016/j.ijpx.2021.100095.
18. Bate, A., & Hobbiger, S. (2020). Artificial Intelligence, Real-World Automation and the Safety of Medicines. Drug Safety, 44, 125 - 132. https://doi.org/10.1007/s40264-020-01001-7.
19. Wang, Y., Zhou, W., Li, Y., & Sun, J. (2025). Business Optimization of Financial Centers in Pharmaceutical Enterprises Based on Robotic Process Automation Technology. IEEE Access, 13, 51012-51026. https://doi.org/10.1109/ACCESS.2025.3550962.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue VII, July 2025

20. Rammal, D., Alomar, M., & Palaian, S. (2024). AI-Driven pharmacy practice: Unleashing the revolutionary potential in medication management, pharmacy workflow, and patient care. Pharmacy Practice. https://doi.org/10.18549/pharmpract.2024.2.2958.
21. Su, X., Wang, Y., Mao, J., Chen, Y., Yin, A., Zhao, B., Zhang, H., & Liu, M. (2022). A Review of Pharmaceutical Robot Based on Hyperspectral Technology. Journal of Intelligent & Robotic Systems, 105. https://doi.org/10.1007/s10846-022-01602-7.
22. Maher-Loughnan, Á., McAuley, C., Laffey, P., & Kearns, M. (2025). Use of a Dispensing Robot to Enhance Capacity for Community Pharmacy Workforce. International Journal of Integrated Care. https://doi.org/10.5334/ijic.icic24535.
23. Bruzzone, L., & Nodehi, S. (2022). Application of Half-Derivative Damping to Cartesian Space Position Control of a SCARA-like Manipulator. Robotics, 11, 152. https://doi.org/10.3390/robotics11060152.
24. Wöhle, L., & Gebhard, M. (2021). Towards Robust Robot Control in Cartesian Space Using an Infrastructureless Head- and Eye-Gaze Interface. Sensors (Basel, Switzerland), 21. https://doi.org/10.3390/s21051798.
25. Kronig, L., Hörler, P., Caseiro, S., Grossen, L., Araújo, R., Kneib, J., & Bouri, M. (2020). Precision control of miniature SCARA robots for multi-object spectrographs. International Journal of Optomechatronics, 14, 53 - 77. https://doi.org/10.1080/15599612.2020.1829218.
26. Li, Y., Gao, J., Chen, W., Zhou, Y., & Yin, Z. (2024). Simulation and trajectory optimization of articulated robots via spectral variational integrators. Commun. Nonlinear Sci. Numer. Simul., 131, 107877. https://doi.org/10.1016/j.cnsns.2024.107877.