

## Hospital Leading Improvements: Discrete Event Simulation as a Strategy to Reduce Patient Length of Stay in the Emergency Department

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### ABSTRACT

The Emergency Department (ED) frequently encounters operational challenges such as overcrowding, prolonged waiting times, and inefficient patient flow, which negatively impact healthcare service delivery. Therefore, several efforts can be made to improve efficiency and service quality through systematic events improvement. The Discrete Event Simulation (DES) could be a promising effort to effectively alleviate the patients' Length of Stay (LOS). This study aimed to assess the role of DES in reducing patient LOS and improving ED efficiency. A literature review was conducted by analyzing peer-reviewed articles published in the past five years from databases including Google Scholar, PubMed, and ProQuest, using specific keywords related to DES and ED performance. The selected studies were synthesized to evaluate the effectiveness of DES interventions. Findings indicate that DES models, particularly when applied through scenario-based simulations, consistently demonstrate significant reductions in ED LOS. These outcomes suggest that DES is a valuable decision-support tool for optimizing resource allocation and patient flow. However, implementation requires careful consideration of institutional needs and further validation through real-world trials. Future research should focus on context-specific applications and long-term impact assessment to support sustainable improvements in emergency care.

### INTRODUCTION

Hospital plays significant roles in the health sectors through various health services to improve the client's health (Triana et al., 2024). Hospital services are represented through various services,

including emergency services. Emergency services play a fundamental role in hospitals. They are characterized by high-pressure conditions, rapid patient assessment requirements, and the provision of immediate medical action (Labrague, 2024). This condition also involves several ER processes that require high dynamics, such as fast response times (Imam et al., 2024), triage processes (Fekonja et al., 2023), examinations and treatment delivery (Sartini et al., 2022), admission (Mostafa & El-Atawi, 2024), or inter-unit transfer or discharge (Mamalelala et al., 2022). This condition will be directly proportional to the increasing of ED visits.

The rise in ED visits is associated with prolonged patient stay in the ED and is regarded as a major concern for the hospital's frontline services. This situation also highlights limitations in hospital capacity to deliver efficient care, reflecting systemic and resource constraints, and contributes to extended LOS for patients.

LOS in the ED refers to the duration from a patient's arrival until subsequent processes occur, such as inter-unit transfer, hospital admission, or further diagnostic evaluation (Harahap et al., 2022). LOS has the characteristics of a normal time range. For instance, in Australia, which stated the reasonable limit of LOS has to be below 4 hours (Forero et al., 2019). However, it is found differently in many other areas, such as Canada and the United Kingdom (Lauque et al., 2022). The prolonged LOS in ED is characterized by an inappropriate extension period before final discharge from an in-hospital bed or inter-facility transfer, which adversely affects clinical outcomes (Lauque et al., 2022). Due to its significant effect, supporting the ED' efficiency and effectiveness is essential.

Enhancing the effectiveness and efficiency of emergency departments can be achieved through multiple approaches, such as AI (Moulik et al., 2020; Triana et al., 2024), process improvement approaches (Volohtchuk & Leite, 2022), and discrete event simulation (Baril et al., 2019; Castanheira-Pinto et al., 2021; Easter et al., 2019; Ofori et al., 2020; Savioli et al., 2022; Tian et al., 2023).

The implementation of DES in hospitals, especially in ED, has been documented in previous studies. A study evaluates the operational efficiency of the ER by combining the Agent-Based Simulation (ABS) and DES approaches equipped with an anomaly detection system. The study highlights the challenges of the ED, such as the increasing number of patients and resource constraints, and how simulation can help in the effective planning and management of resources (Effendi et al., 2024) . Another study conducted in Italy also employed DES and was intended as an input effort in organizational change to improve the key performance indicator related to patient satisfaction, LOS. This simulation model is based on historical data, observations of the current situation of the ED, and information from the ED staff. The results help to evaluate the impact of various remediation scenarios (Dosi et al., 2023).

The DES model is defined as a simulation approach that represents a real system and its environment through simulated scenarios, enabling the exploration of specific concepts, principles, or processes (Pooch & Wall, 2024). The process is employed to imitate the system and describe it in general terms by considering the key characteristic properties of the system's activities. Simulation does not produce an answer to a problem but a way to overcome it (Mourtzis, 2020).

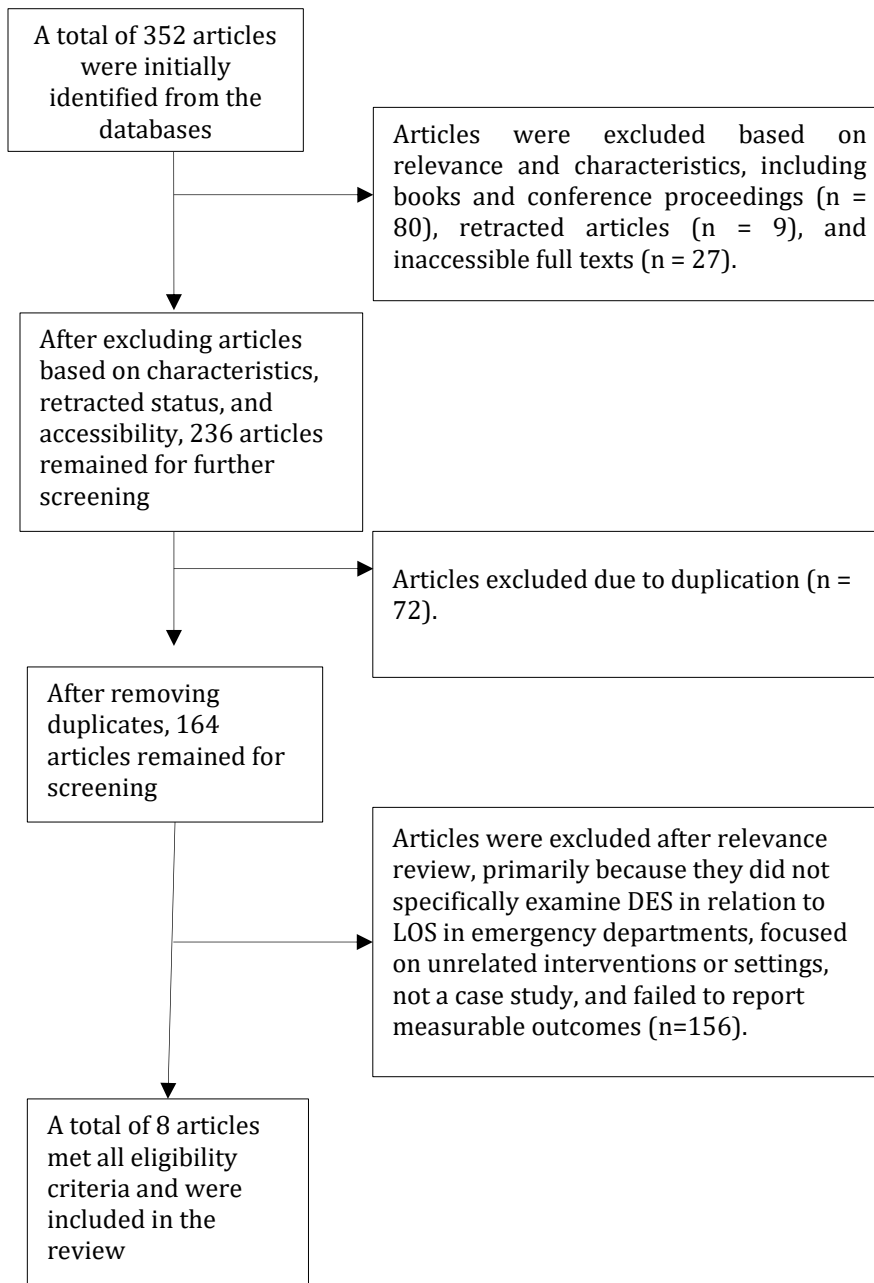
DES model is frequently adopted to evaluate and identify optimal solutions for improving healthcare service systems. This method has been widely applied to enhance production capacity, cost efficiency, timeliness, quality of performance, energy efficiency, safety, and overall productivity. Moreover, DES contributes to reducing failure rates in meeting standard targets, minimizing unexpected events, optimizing resource allocation, and improving system performance (Ouda et al., 2023). By simplifying the process, the goal is to achieve a faster response to urgent medical situations and reduce patient wait times (Triana et al., 2024). This condition means ensuring that resources, from medical staff to equipment, are used optimally to improve the overall ED readiness (Igra et al., 2024). These initiatives have the potential to substantially enhance the efficiency and effectiveness of the ED (Triana et al., 2024).

Several studies have been conducted related to the implementation of DES in ED and were known to have massive results. However, there is a research gap in understanding the application of DES in EDs, especially to improve efficiency in reducing LOS. This study was conducted to examine the role of DES and its implementation in the ED to reduce LOS. The primary objective was to assess the impact of DES on mitigating LOS in the ED.

## **RESEARCH METHODS**

We conducted a literature review by analyzing peer-reviewed research articles retrieved from Google Scholar, PubMed, and ProQuest, using defined keywords over the past five years (January 2019–January 2024). The search was limited to articles published in English or Indonesian, focusing on DES and LOS in ED. The search strategy employed specific keywords and Boolean operators, including 'DES' OR 'Discrete Event Simulation' OR 'Modeling' AND 'Emergency Department' OR 'ED' OR 'ER' AND 'Length of Stay' OR 'LOS.' Studies were included if they examined DES as an intervention and reported positive outcomes in reducing LOS in ED. No journal accreditation appraisal was conducted for this review (see Diagram 1)

During the search strategy, we employed inclusion criteria such as (1) Peer-reviewed journal articles; (2) Published between 2018 and 2023; (3) Focused on the use of DES in ED settings; (4) Reported on outcomes related to patient length of stay, throughput, or resource optimization; (5) Full text available in English or Indonesian. The exclusion criteria namely (1) Conference abstracts, editorials, commentaries, and theses; (2) Studies unrelated to ED or that used simulation methods other than DES (e.g., system dynamics or agent-based modelling without DES components) (3) Articles without sufficient methodological detail or outcome data. The study titles and abstracts were screened independently by three reviewers (L.T., V.P., & R.S). Full-text articles were then retrieved for potentially eligible studies. Discrepancies during screening were resolved through discussion or adjudicated by a third reviewer to ensure consistency (E.D.Y).



**Figure 1. Research Flow Diagram**

## RESULTS

Table 1. Reviewed Relevant Articles

No	Author	Design	Outcomes			Specific Findings
			LOS	Flow	Wait times	
1.	Zamani (2022)	Case Study	x	x		[1] LOS was reduced by 16%. [2] LOS was reduced by 32% on all Emergency Severity Index levels.
2.	Gabriel et al. (2020)	Case Study	x			[1] LOS was 2213.7 and reduced to 461.2 minutes
3.	McKinley et al. (2021)	Case Study	x	x	x	[1] Differences in length of stay (LOS) were observed, ranging from 19.1 minutes for patients with Emergency Severity Index (ESI) level 4 to 10.9 minutes for those with ESI level 5 [2] Mean waiting time differences were also identified, decreasing from 8.9 minutes at ESI level 4 to 7.4 minutes at ESI level 5
4.	Easter et al. (2019)	Case Study	x	x	x	[1] Both simulation models demonstrated statistically significant results [2] Length of stay (LOS) was reduced by 10.6 to 21.8 minutes [3] Bed utilization increased by 0.23 to 0.40 patients per bed per day [4] Door-to-physician (D2P) time decreased by 1.3 to 4.8 minutes [5] Left without being seen (LWBS) rates were reduced by 0.66% to 2.0%
5.	Hamza et al. (2021)	Case Study	x		x	[1] The 1 <sup>st</sup> simulation known to have higher efficiency to reduce waiting time other than the four alternatives model applied. [2] The overall average waiting time performance of the 1 <sup>st</sup> simulation is higher 74,58% compared to the four models

No	Author	Design	Outcomes			Specific Findings
			LOS	Flow	Wait times	
						[3] The LOS significantly alleviated by the greater waiting time compared to other 4 models by 85.6%
6.	Ferreira et al. (2023)	Case Study	x	x	x	[1] Showed an improvement regarding patient flow as well as LOS with a decrease of up to 30 minutes.
7.	Baril et al. (2019)	Case Study	x		x	[1] By implementing collective prescriptions at the ED's triage reduces LOS by 30% [2] Adding a professional nurse's practitioner per shift could reduce LOS by 29%.
8.	Valipoor, et al. (2021)	Case Study	x	x	x	[1] The Hallway care Scenarios resulted to Lowering the LOS significantly [2] Both combined scenarios can reduce LOS and exam room time

## DISCUSSION

ED encounter significant challenges due to high workload and dynamic environments, including growing demands to deliver efficient care while addressing issues of overcrowding, prolonged LOS, safety concerns, delays, and staffing constraints (Triana et al., 2024). Those highlighted in a study (Bal et al., 2017), which stated that excessive overcrowding in the ER can lead to adverse effects such as increased LOS, which is associated with higher mortality rates. However, non-urgent patients were admitted to the ED, which made it even more crowded (Allen et al., 2021; Baykan et al., 2021). This condition will lead to an increasing workload and, on the contrary, will contribute negatively to performance (Triana, 2017).

Efforts to improve the performance of Eds require targeted solutions. Optimizing patient flow, alleviating congestion, and balancing workload are key priorities in this process. DES serves as a modeling approach that replicates real systems and their environments through simulated scenarios, enabling the exploration of specific concepts, principles, and operational strategies (Pooch & Wall, 2024). When focused on the emergency ED, DES can significantly improve operational efficiency by reducing the LOS by simplifying workflows and optimizing resources (Srinivas et al., 2021).

Our literature review identified several applicable scenarios for emergency departments aimed at reducing patients' LOS. Some of these scenarios vary from the rapid admit protocol and results pending protocol (Zamani, 2022) to the ED's flow and physical design (Easter et al., 2019), triage and hallway care (Valipoor et al., 2021), exit ped and bed turnover scenarios (McKinley et al., 2021), and

employed varies (Baril et al., 2019; Ferreira et al., 2020; Gabriel et al., 2020; Hamza et al., 2021) (Table 1).

Our study revealed that several DES-related interventions, as reported in the literature, have contributed substantially to positive advancements in ED performance. A study by Valipoor et al., (2021), through their research by applying protocols (see Table 1), has been proven to reduce patients' LOS by a significant percentage (Valipoor et al., 2021). The simulation model offers the possibility of assessing the value of potential alternatives in an economically feasible and timely manner (Pooch & Wall, 2024).

DES is a valuable approach for assessing congestion in ED using data-driven evaluation. It has been widely applied in prior studies to elucidate underlying conditions and barriers within the ED, thereby offering critical insights into potential improvement strategies and enabling the assessment of their impact on LOS. (Srinivas et al., 2021). By utilizing DES, ED gets a better view of a more optimal system through the application of design suggestions and alternative improvements that lead to positive outcomes such as waiting time efficiency (Baril et al., 2019; Easter et al., 2019; Ferreira et al., 2020; Hamza et al., 2021; McKinley et al., 2021; Valipoor et al., 2021), simplifying patient's flow (Easter et al., 2019; Ferreira et al., 2020; McKinley et al., 2021; Valipoor et al., 2021; Zamani, 2022) and the LOS alleviation as shown on the table 1.

The successful implementation of DES in the healthcare sector requires careful consideration of multiple success factors, including financial resources, human capital, and technological capacity, all of which are essential for optimizing hospital processes, as outlined by Olajide et al. (2019). In addition, integrating DES modelling frameworks or scenarios offers a promising solution to efficiently allocate workloads between resources economically (Srinivas et al., 2021). DES' modelling provides an effective approach to evaluating potential process improvement strategies, enabling healthcare professionals to perform effectively in the ED's.

The majority of study findings consistently demonstrate the effectiveness of DES in optimizing ED operations and reducing patient LOS. Evidence shows that targeted resource reallocation and improvements in triage flow can significantly decrease average LOS without necessitating major structural changes. In contrast to earlier studies that relied primarily on assumed or literature-based service time distributions, most of the reviewed literature employed real-world hospital data and stakeholder input, thereby enhancing both accuracy and applicability. Furthermore, while prior research has often been constrained by limited validation, the models examined in our review were cross-validated against historical performance metrics and refined through staff engagement workshops, strengthening their credibility and contextual relevance. These comparisons underscore not only the robustness of DES as a strategic planning tool but also the importance of tailoring simulation parameters to institutional contexts. Accordingly, this review contributes a more validated, data-driven application of DES with practical implications for ED operations management

DES also offers a promising strategy to broadly improve operational efficiency in emergency departments. Based on a literature study conducted, a case study by Zamani (2022) explained that the implementation of DES improves service quality through a decrease in LOS by 16.32 minutes,

respectively. This condition resulted in significant outcomes. By rethinking and redesigning core processes, ED can better manage patient flow, reduce patient overcrowding, and improve service quality (Baril et al., 2019). Systematic implementation of DES allows for improved patient outcomes and operational performance, addressing the complexity of emergency department operations (Valipoor et al., 2021). Hospitals can significantly improve outcomes and resource utilization through innovative approaches, ensuring timely and effective patient care. Overall, DES functions as a catalyst to achieve a comprehensive improvement in emergency departments, setting an example for improving healthcare delivery.

## CONCLUSION

This study underscores the potential benefits of DES in emergency departments (EDs). Our findings suggest that DES should be considered a key intervention for alleviating patient length of stay (LOS). By modeling alternative scenarios, DES offers valuable solutions for enhancing the quality of ED services. However, prior to implementation, an initial analysis is essential to determine the most suitable scenarios for system modification. To establish a comprehensive approach, further research is warranted to examine and evaluate each scenario in greater depth.

## REFERENCES

- Allen, L., Cummings, J. R., & Hockenberry, J. M. (2021). The impact of urgent care centers on nonemergent emergency department visits. *Health Services Research, 56*(4), 721–730. <https://doi.org/10.1111/1475-6773.13631>
- Bal, A., Ceylan, C., & Taçoğlu, C. (2017). Using value stream mapping and discrete event simulation to improve efficiency of emergency departments. *International Journal of Healthcare Management, 10*(3), 196–206. <https://doi.org/10.1080/20479700.2017.1304323>
- Baril, C., Gascon, V., & Vadeboncoeur, D. (2019). Discrete-event simulation and design of experiments to study ambulatory patient waiting time in an emergency department. *Journal of the Operational Research Society, 70*(12), 2019–2038. <https://doi.org/10.1080/01605682.2018.1510805>
- Baykan, O., Meral, O., Ozturk, T., & Gonullu, H. (2021). *Characteristics of non-urgent visits in emergency department*. <https://doi.org/10.5455/annalsmedres.2020.06.592>
- Castanheira-Pinto, A., Gonçalves, B. S., Lima, R. M., & Dinis-Carvalho, J. (2021). Modeling, assessment and design of an emergency department of a public hospital through discrete-event simulation. *Applied Sciences, 11*(2), 805. <https://doi.org/10.3390/app11020805>
- Dosi, C., Iori, M., Kramer, A., & Vignoli, M. (2023). Successful implementation of discrete event simulation: integrating design thinking and simulation approach in an emergency department. *Production Planning & Control, 34*(13), 1233–1247. <https://doi.org/10.1080/09537287.2021.1996651>
- Easter, B., Houshiarian, N., Pati, D., & Wiler, J. L. (2019). Designing efficient emergency departments:

- Discrete event simulation of internal-waiting areas and split flow sorting. *The American Journal of Emergency Medicine*, 37(12), 2186–2193. <https://doi.org/10.1016/j.ajem.2019.03.017>
- Effendi, Y. A., Setyaningtyas, S. W., & Sarno, R. (2024). Evaluating the Impact of COVID-19 on Emergency Department Operations: A Combined Agent-Based and Discrete Event Simulation Model with Anomaly Detection. *International Journal of Intelligent Engineering and Systems*, 17(6), 763–778. <https://doi.org/10.22266/ijies2024.1231.58>
- Fekonja, Z., Kmetec, S., Fekonja, U., Mlinar Reljić, N., Pajnikihar, M., & Strnad, M. (2023). Factors contributing to patient safety during triage process in the emergency department: A systematic review. *Journal of Clinical Nursing*, 32(17–18), 5461–5477.
- Ferreira, D. C., Vieira, I., Pedro, M. I., Caldas, P., & Varela, M. (2023). Patient Satisfaction with Healthcare Services and the Techniques Used for its Assessment: A Systematic Literature Review and a Bibliometric Analysis. *Healthcare*, 11(5), 639. <https://doi.org/10.3390/healthcare11050639>
- Ferreira, L. A. F., Santos, I. L. dos, Santos, A. C. de S. G. dos, & Reis, A. da C. (2020). Discrete event simulation for problem solving in the context of an emergency department. *Independent Journal of Management & Production*, 11(5), 1515–1531. <https://doi.org/10.14807/ijmp.v11i5.1286>
- Forero, R., Man, N., Ngo, H., Mountain, D., Mohsin, M., Fatovich, D., Toloo, G. (Sam), Celenza, A., FitzGerald, G., McCarthy, S., Richardson, D., Xu, F., Gibson, N., Nahidi, S., & Hillman, K. (2019). Impact of the four-hour National Emergency Access Target on 30 day mortality, access block and chronic emergency department overcrowding in Australian emergency departments. *Emergency Medicine Australasia*, 31(1), 58–66. <https://doi.org/10.1111/1742-6723.13151>
- Gabriel, G. T., Campos, A. T., Magacho, A. de L., Segismondi, L. C., Vilela, F. F., de Queiroz, J. A., & Montevechi, J. A. B. (2020). Lean thinking by integrating with discrete event simulation and design of experiments: an emergency department expansion. *PeerJ Computer Science*, 6, e284. <https://doi.org/10.7717/peerj-cs.284>
- Hamza, N., Majid, M. A., & Hujainah, F. (2021). SIM-PFED: A Simulation-Based Decision Making Model of Patient Flow for Improving Patient Throughput Time in Emergency Department. *IEEE Access*, 9, 103419–103439. <https://doi.org/10.1109/ACCESS.2021.3098625>
- Harahap, A. A., Rayasari, F., Besral, B., Irawati, D., & Kurniasih, D. N. (2022). Analisa Faktor yang Berhubungan dengan Length of Stay (LOS) id IGD. *Jurnal Keperawatan*, 14(3), 821–830. <https://journal2.stikeskendal.ac.id/index.php/keperawatan/article/view/462>
- Igra, N. M., Schmulevich, D., Geng, Z., Guzman, J., Biddinger, P. D., Gates, J. D., Spinella, P. C., Yazer, M. H., & Cannon, J. W. (2024). Optimizing Mass Casualty Triage: Using Discrete Event Simulation to Minimize Time to Resuscitation. *Journal of the American College of Surgeons*, 238(1), 41–53. <https://doi.org/10.1097/XCS.0000000000000894>
- Labrague, L. J. (2024). Relationship between transformational leadership, adverse patient events, and nurse-assessed quality of care in emergency units: The mediating role of work satisfaction. *Australasian Emergency Care*, 27(1), 49–56. <https://doi.org/10.1016/j.auec.2023.08.001>

- Lauque, D., Khalemsky, A., Boudi, Z., Östlundh, L., Xu, C., Alsabri, M., Onyeji, C., Cellini, J., Intas, G., Soni, K. D., Junhasavasdikul, D., Cabello, J. J. T., Rathlev, N. K., Liu, S. W., Camargo, C. A., Slagman, A., Christ, M., Singer, A. J., Houze-Cerfon, C.-H., ... Bellou, A. (2022). Length-of-Stay in the Emergency Department and In-Hospital Mortality: A Systematic Review and Meta-Analysis. *Journal of Clinical Medicine*, 12(1), 32. <https://doi.org/10.3390/jcm12010032>
- Mamalelala, T. T., Mokone, D. J., & Obeng-Adu, F. (2022). Health-related reasons patients transfer from a clinic or health post to the Emergency Department in a District Hospital in Botswana. *African Journal of Emergency Medicine*, 12(4), 339–343. <https://doi.org/10.1016/j.afjem.2022.07.014>
- McKinley, K. W., Chamberlain, J. M., Doan, Q., & Berkowitz, D. (2021). Reducing Pediatric ED Length of Stay by Reducing Diagnostic Testing: A Discrete Event Simulation Model. *Pediatric Quality & Safety*, 6(2), e396. <https://doi.org/10.1097/pq9.0000000000000396>
- Mostafa, R., & El-Atawi, K. (2024). Strategies to measure and improve emergency department performance: a review. *Cureus*, 16(1).
- Moulik, S. K., Kotter, N., & Fishman, E. K. (2020). Applications of artificial intelligence in the emergency department. *Emergency Radiology*, 27(4), 355–358. <https://doi.org/10.1007/s10140-020-01794-1>
- Mourtzis, D. (2020). Simulation in the design and operation of manufacturing systems: state of the art and new trends. *International Journal of Production Research*, 58(7), 1927–1949. <https://doi.org/10.1080/00207543.2019.1636321>
- Nurul Imam, Taufan Citra Darmawan, Siska Christianingsih, & Khalifatus Zuhriyah Alfianti. (2024). Factors Affecting Nurse Response Time in Indonesian Hospital Emergency Installation: A Literature Review. *Nursing and Health Sciences Journal (NHSJ)*, 4(2), 227–238. <https://doi.org/10.53713/nhsj.v4i2.372>
- Ofori, D. A., Anjarwalla, P., Mwaura, L., Jamnadass, R., Stevenson, P. C., Smith, P., Koch, W., Kukula-Koch, W., Marzec, Z., Kasperek, E., Wyszogrodzka-Koma, L., Szwerc, W., Asakawa, Y., Moradi, S., Barati, A., Khayyat, S. A., Roselin, L. S., Jaafar, F. M., Osman, C. P., ... Slaton, N. (2020). No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析 Title. *Molecules*, 2(1), 1–12. <http://clik.dva.gov.au/rehabilitation-library/1-introduction-rehabilitation%0Ahttp://www.scirp.org/journal/doi.aspx?DOI=10.4236/as.2017.81005%0Ahttp://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/as.2012.34066%0Ahttp://dx.doi.org/10.1016/j.pbi.201>
- Olajide, O. T., Lawal, O. R., & Alaka, S. N. (2019). Effects of Business Process Re-Engineering on Performance of Selected Hospitals In Lagos State. *Annals of the University of Craiova, Economic Sciences Series*, 2(48).
- Ouda, E., Sleptchenko, A., & Simsekler, M. C. E. (2023). Comprehensive review and future research agenda on discrete-event simulation and agent-based simulation of emergency departments. *Simulation Modelling Practice and Theory*, 129, 102823. <https://doi.org/10.1016/j.simpat.2023.102823>
- Pooch, U. W., & Wall, J. A. (2024). *Discrete event simulation: a practical approach*. CRC press.

- Sartini, M., Carbone, A., Demartini, A., Giribone, L., Oliva, M., Spagnolo, A. M., Cremonesi, P., Canale, F., & Cristina, M. L. (2022). Overcrowding in emergency department: causes, consequences, and solutions—a narrative review. *Healthcare, 10*(9), 1625.
- Savioli, G., Ceresa, I. F., Gri, N., Bavestrello Piccini, G., Longhitano, Y., Zanza, C., Piccioni, A., Esposito, C., Ricevuti, G., & Bressan, M. A. (2022). Emergency Department Overcrowding: Understanding the Factors to Find Corresponding Solutions. *Journal of Personalized Medicine, 12*(2), 279. <https://doi.org/10.3390/jpm12020279>
- Srinivas, S., Nazareth, R. P., & Shoriat Ullah, M. (2021). Modeling and analysis of business process reengineering strategies for improving emergency department efficiency. *SIMULATION, 97*(1), 3–18. <https://doi.org/10.1177/0037549720957722>
- Tian, Y., Basran, J., Stempien, J., Danyliw, A., Fast, G., Falastein, P., & Osgood, N. D. (2023). Participatory Modeling with Discrete-Event Simulation: A Hybrid Approach to Inform Policy Development to Reduce Emergency Department Wait Times. *Systems, 11*(7), 362. <https://doi.org/10.3390/systems11070362>
- Triana, I. K. D. L. (2017). Manajemen Stres Kerja Perawat Pelaksana: Dihubungkan Dengan Self-Management, Self-Efficacy, Dan Beban Kerja Di Instalasi Rawat Inap Rumah Sakit. *Bimiki (Berkala Ilmiah Mahasiswa Ilmu Keperawatan Indonesia), 5*(2), 29–36. <https://bimiki.ejournal.id/bimiki/article/view/108>
- Triana, I. K. D. L., Agustina, P. D. C., Febrian, R., Wiadnya, I. D. G. P., & Paramarta, V. (2024). Streamlining Emergency Department Efficiency: Implementing Business Process Re-Engineering To Reduce Patient Wait Times. *Homes Journal: Hospital Management Studies Journal, 5*(2), 120–131. <https://doi.org/10.24252/hmsj.v5i2.46369>
- Valipoor, S., Hatami, M., Hakimjavadi, H., Akçali, E., Swan, W. A., & De Portu, G. (2021). Data-Driven Design Strategies to Address Crowding and Boarding in an Emergency Department: A Discrete-Event Simulation Study. *HERD: Health Environments Research & Design Journal, 14*(2), 161–177. <https://doi.org/10.1177/1937586720969933>
- Volochtchuk, A. V. L., & Leite, H. (2022). Process improvement approaches in emergency departments: a review of the current knowledge. *International Journal of Quality & Reliability Management, 39*(2), 495–520. <https://doi.org/10.1108/IJQRM-09-2020-0330>
- Zamani, Z. (2022). Leveraging discrete event simulation modeling to evaluate design and process improvements of an emergency department. *Journal of Design for Resilience in Architecture and Planning, 3*(3), 397–408. <https://doi.org/10.47818/DRArch.2022.v3i3064>