The crisis in the French healthcare system

Solutions to relieve congestion in emergency departments

By Benjamin Legros, Frédérique Vidal and Sean Scull

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INTRODUCTION

'As before the pandemic, emergency departments have once again become the catch-all for much of the health system's overflow. As the last resort, they are themselves under strain, being called upon not only for genuine emergencies, but also by patients unable to secure a timely GP appointment and by those with chronic conditions not receiving regular medical follow-up care[1]*.'*

This statement is from the report entitled *'L'accueil et le traitement des urgences à l'hôpital'(Hospital Reception and Management of Emergency Cases),* published by the French Court of Auditors (Cour des Comptes) in November 2024. The report is alarming, describing a healthcare system under severe strain due to overstretched departments struggling to cope with ever-increasing demand. To resolve this issue, the Court of Auditors' report stresses the urgent need to review the patient pathway prior to attendance at the emergency department (ED, commonly known as A&E in the UK, for Accidents and Emergencies). Indeed, departments that care for patients requiring unscheduled treatment are complex systems, dealing with unpredictable demand and limited resources, often resulting in long waiting times. These situations have a direct impact on quality of care, patient safety, and operational efficiency.

This SKEMA Publika policy paper draws on the work of Benjamin Legros to show how mathematical tools and models can be used to analyse, understand and optimise queue management in emergency departments, while also taking into account human and organisational factors. It explores the application of queueing theories and other mathematical approaches to address the challenges of emergency departments by modelling patient arrival processes, analysing risk aversion, proposing patient prioritisation strategies, and emphasising staff training and the role of call centres.

The matter examined in this policy paper is highly topical, given the budgetary pressures faced by the French state and, in particular, by public hospitals. Statistics from INSEE, the French National Institute of Statistics and Economic Studies, show that in 2022, la Sécurité Sociale, France's social security system, covered 80% of the French population's healthcare spending[2]. This corresponds to 11.9% of GDP spent on healthcare[3]. Healthcare is therefore one of the state's largest areas of expenditure, and it also places a heavy burden on the public deficit. According to estimates by the Fédération Hospitalière de France (the Hospital Federation of France), hospitals were running a deficit of 3.4 billion euros in 2024[4]. This policy paper is also situated within a political context in which the government is seeking to reduce public debt to 3,305.3 billion euros (2024) and is preparing a fiscal consolidation plan aimed at achieving €40 billion in savings by 2026. Our analysis aims to provide inspiration for these efforts to reduce expenditure, by offering concrete public-policy solutions to ease congestion in emergency departments, thereby contributing to the broader improvement of the French healthcare system. In particular, it challenges the notion that the congestion problem can be resolved solely by allocating more material, financial and human resources. Instead, we present an alternative perspective, arguing that it is more cost-effective to rethink task routing and staff roles, highlighting the value of integrating mathematical models and new digital technologies into this reflection. At the heart of our analysis lies the following question:

- *In a difficult budgetary context, how can patient flow management in emergency departments be optimised?*

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[1] *L'accueil et le traitement des urgences à l'hôpital*. (2024). Cour des Comptes. https://www.ccomptes.fr/fr/publications/laccueil-et-le-traitement-des-urgences-lhopital

[2] *Dépenses de santé − France, portrait social | Insee*. (2023). https://www.insee.fr/fr/statistiques/7666887?sommaire=7666953

[3] La rédaction. (2022). Dépenses de santé : elles ralentissent en 2022 avec le recul du Covid-19. Vie Publique. https://www.vie-publique.fr/en-bref/291168-depenses-de-sante-elles-ralentissent-en-2022-avec-le-recul-du-covid-19

[4] With AFP, F. (2025, May 22). Les hôpitaux ont connu une dégradation « sans précédent » de leurs finances en 2023. *Franceinfo*. https://www.franceinfo.fr/sante/hopital/les-hopitaux-ont-connu-une-degradation-sans-precedent-de-leurs-finances-en-2023_7265832.html

In part one, we explore the theoretical foundations of queueing in emergency departments. Part two examines how game theory can shed light on patient behaviour. In Part three, we focus on the critical issue of patient prioritisation. Part four analyses the role staff training can play in optimising patient flow, while Part five looks at how call centres could help manage patient flow more effectively. Finally, in Part six, we outline the challenges and future possibilities arising from task routing in emergency departments. In addition, this study includes comparisons with emergency systems in other countries, in order to draw inspiration from the public policies in place there and provide concrete recommendations for improving access to care in French emergency departments.

PART ONE

THEORETICAL FOUNDATIONS OF QUEUEING IN EMERGENCY DEPARTMENTS

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Emergency departments, intended for patients requiring urgent care, are experiencing significant congestion. According to a study by France's Directorate for Research, Studies, Evaluation and Statistics (DREES), the waiting time in emergency departments has increased by 45 minutes since 2013. By 2023, the average waiting time had reached 3 hours and 45 minutes[5]. Given how difficult these long waits are for patients, many departments are seeking to understand their causes and identify possible ways to reduce them.

QUEUEING THEORY

To understand waiting times in emergency departments, it is necessary to turn to queueing theory, which originated in 1909 with the work of the Danish engineer A.K. Erlang, who mathematically modelled 'waiting' as the situation in which users are not served immediately. This work was inspired by the problem of congestion in telephone traffic[6].

Let us start with a simple question: why do we wait?

Imagine a supermarket checkout with a single cashier, where each transaction takes five minutes and a customer arrives every six minutes. In this case, no customer waits; the cashier is free each time a new customer arrives. If, however, a customer arrives every four minutes, the dynamics change: the first customer does not wait, the second waits one minute, the third two minutes, the fourth three minutes, and so on. The queue continues to grow and the system becomes unstable, never reaching equilibrium.

At this point, one might think that in practice queues are always either empty or endlessly long... but that is far from the truth! An essential ingredient is missing here: variability. In reality, both service times and the gaps between arrivals are random; sometimes several customers turn up at once, or a transaction takes longer than usual. As a result, periods without waiting alternate with periods of congestion, meaning that even when the average service time is shorter than the average interval between arrivals, some patients, or customers in the case of our example, still end up waiting.

Queueing theory allows this variability to be modelled in order to calculate, among other things, the average waiting time based on the mean service time, the average time between arrivals, and the number of staff available. These formulae help to identify the factors contributing to waiting times and guide decision-making. This process involves making certain assumptions (often simplifying ones): arrivals follow a Poisson process, service times are exponential, and the service discipline is 'first come, first served'. Within this framework, a Markov chain can be analysed, providing explicit expressions for average waiting time, the distribution of waiting times, or staff utilisation rates. These results are essential for deciding, for example, on patient routing or the resources to provide, such as the number of staff or operating theatres[7].

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[5] Kachaner, A. (2025, March 19). Le temps d'attente aux urgences augmente en France. France Inter. https://www.radiofrance.fr/franceinter/podcasts/l-info-de-france-inter/l-info-de-france-inter-3029887

[6] A. K. Erlang, "The theory of probability and telephone conversations", *Nyt Tidsskrift for Matematik*, b, vol. 20, 1909

A. Erlang, "Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges", *Elektrotkeknikeren*, vol. 13, 1917

[7] Cachon, G. and Terwiesch, C. (2019). Operations Management. McGraw Hill Education, New York, 2nd edition.

THE UNIQUE CASE OF EMERGENCY DEPARTMENTS: THE LIMITS OF STANDARD QUEUEING FORMULAE

In a hospital emergency department, conventional, stylised queueing models quickly come up against the complexity of real life. On the one hand, the time it takes to examine or stabilise a patient, perform imaging, or wait for a bed to become available downstream can be long and highly variable. The system therefore usually operates in a transient regime, far removed from the stationary state assumed in the theory's formulae. On the other hand, the flow of arrivals is not constant: it follows marked hourly, daily, and seasonal patterns, making it necessary to model these flows and understand patient behaviour. For example, there may be a high influx of patients in the evenings, on Mondays, or following a flu outbreak, then a lull in the early morning. To capture these variations, which stem from the unpredictable nature of emergency departments, non-homogeneous Poisson processes, cyclic models, or more sophisticated time-series analyses must be employed.

Service-time distributions also deviate from the exponential, with log-normal or phase-type distributions frequently observed. Added to this is the triage logic: each patient is classified according to severity, so the queue operates with multiple priority levels, with life-threatening emergencies taking precedence over less severe cases. This is far removed from a simple 'first come, first served' approach. Moreover, a significant fraction of patients leave without being seen, sometimes because they cannot or will not wait any longer, or sometimes to return within 72 hours when a complication arises. These behaviours, known as balking, reneging, and retrial, add to the effective workload and complicate capacity planning.

Emergency department overcrowding is not solely due to the front-line medical service: cross-department bottlenecks (laboratory, radiology, availability of downstream beds) lead to boarding, where stabilised patients are kept in ED bays for lack of an inpatient bed. This results in networks of finite-capacity queues, inter-department blockages, and a dynamically evolving clinical risk.

To address this complexity, research combines analytical extensions (non-stationary processes, general service distributions, nested-priority queues, blocking networks, return processes) with numerical approaches (discrete-event simulation, or even digital twins) that reproduce patient pathways, staff scheduling, and resource availability on a minute-by-minute basis. These tools support decision-making beyond intuition, by quantifying, for example, the impact of an additional nurse, a dedicated scanner, or a rapid observation unit on waiting times, current and future system saturation, and the effects of patient care policies on health outcomes.

PART TWO

GAME THEORY TO UNDERSTAND PATIENT BEHAVIOUR

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One major factor behind emergency department congestion is the lack of regulation of admission flows. Patients are free to attend the emergency department rather than make an appointment with their general practitioner (GP). As these emergency care services are free, easily accessible, and staffed by highly qualified practitioners, they are attractive to the population, including patients with non-life-threatening health issues.

OVERCROWDING DUE TO FAILING TO ACCOUNT FOR NEGATIVE EXTERNALITIES

Game theory offers valuable insight into the decision-making of patients who nonetheless choose to attend an overcrowded emergency department. Paul Naor's seminal model (1969)[8] shows that each patient seeks to maximise a utility function that decreases with waiting time: the longer the queue, the less attractive it should be. Yet, in practice, persistent overcrowding and a near-total absence of self-regulation are observed. As highlighted by Hassin and Haviv (2003)[9], this paradox is explained by the incomplete consideration of externalities: when ED managers admit a patient, they take into account both the waiting time the patient will experience and the additional delay imposed on others, whereas the individual considers only their own interest. The result is an equilibrium in which queues remain too long and resources are overstretched.

A combination of measures can help reduce this overload. First, triage at the ED entrance can limit the admission of less urgent cases, although distinguishing between a patient's actual and perceived state remains tricky. Second, introducing a modest, or symbolic, admission fee would discourage non-essential visits: truly urgent patients would accept this cost, while others would likely choose to consult a GP instead. However, this would raise ethical debates around the principle of free care. Finally, educating the public and raising awareness of negative externalities, as proposed by Legros and van Leeuwaarden (2025)[10] with the concept of "Wait Externality Awareness", can foster greater patient responsibility. However, the impact of such campaigns remains uncertain and costly.

There is therefore no single solution to emergency department congestion; however, a pragmatic combination of these three approaches, namely intelligent triage, symbolic admission fees, and public information, can help relieve pressure on services while preserving access for genuinely critical cases.

PATIENT WAITING-TIME RISK AVERSION: AN AMPLIFIER OF CONGESTION

A recent empirical study shows that patients are concerned not only with the average waiting time, but with the entire distribution of waiting times[11]. The authors highlight a risk aversion effect: a patient evaluates not only the average waiting time, but also the probability of waiting 'longer than…', compared to the expected benefit of the service.

This aversion amplifies queue congestion, as it cancels out the beneficial effect that increasing capacity could bring. Legros, van Leeuwaarden, de Véricourt and Fransoo (2024)[12] demonstrate that increasing capacity, whether in terms of staff, operating theatres, or other resources, can paradoxically lengthen equilibrium waiting times.

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[8] Naor, P. (1969). The Regulation of Queue Size by Levying Tolls. *Econometrica: journal of the Econometric Society*, 15-24.

[9] Hassin, R., & Haviv, M. (2003). *To Queue or Not to Queue: Equilibrium Behavior in Queueing Systems (Vol. 59).* Springer Science & Business Media.

[10] Legros, B., & van Leeuwaarden, J. (2025). Wait Externality Awareness for Socially Responsible Queueing. *Available at SSRN 5182011.*

[11] Kagan, E., Hyndman, K. B., & Davis, A. M. (2024). Beyond Averages: How Do Customers Respond to Wait Time Distributions?. *Available at SSRN 4899240*.

[12] Legros, B., van Leeuwaarden, J., de Véricourt, F., & Fransoo, J. C. (2024). Risk Aversion Undermines Benefits of Capacity Expansion in Services. *Available at SSRN 4977597.*

When capacity is increased, the average waiting time and its variability fall, making the service more attractive to risk-averse patients. This resulting additional influx eventually overwhelms the new capacity, causing waiting times to rise again, sometimes even higher than before the capacity increase. This phenomenon is well known in the field of urban planning: when a motorway is widened, the extra capacity attracts more drivers, and the traffic jams the expansion was intended to solve then soon reappear.

To prevent such rebound effects from worsening congestion, several avenues emerge: accurately assessing patients' waiting-time risk aversion, since it drives demand responses; favouring a network of smaller urgent treatment centres rather than centralising EDs in large hospitals, to limit the excessive attractiveness of convenient one-stop services; and reliably displaying waiting times using robust predictive models. In the longer term, artificial intelligence (NLP, deep learning) could support automated pre-triage to redirect patients before they present at the ED, smooth patient flow, improve prediction accuracy, and reduce the impact of risk aversion.

PART THREE

THE CRITICAL ISSUE OF PATIENT PRIORITISATION

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A key element in managing congestion and patient acuity is task scheduling, which is guided by prioritisation policies. Acuity essentially determines the order in which patients will be treated: colours (blue, green, red) are assigned to indicate urgency levels, and within each category a 'first come, first served' rule applies, with necessary exceptions.

However, classifying patients by acuity is not as straightforward as it may appear. When the ED is less congested, some procedures considered lower priority can become more pressing; conversely, in busy periods, moderately severe cases may be kept waiting. Moreover, urgency cannot be determined solely from an initial assessment on arrival; it also depends on comorbidities, the severity of the patient's condition, and the time they have spent waiting. Prioritisation (or routing) policies are therefore closely tied to the system's real-time state.

One powerful tool for establishing truly optimal policies is dynamic programming, based on Markov Decision Processes (MDP). It breaks down a sequential problem into successive sub-problems: each system state is assigned a 'value' reflecting the expected future cost (postponed procedures, abandonments, mortality, etc.) associated with a particular decision. The Bellman equation, at the heart of the method, allows one to work backward from the end point to the present and identify, at each step, the decision that minimises the total cost. In practice, this produces conditional rules that are often very simple: for example, 'if the number of red-category patients exceeds N, deprioritise new green cases until the queue clears.'

In his book, Puterman (2014)[13] describes the application of this tool in detail and shows that optimal policies have a threshold structure: once the number of patients in the queue exceeds a certain point, it becomes rational to delay less critical cases in order to avoid excessive waiting times for the serious cases already present.

However, deploying such policies is challenging: they require an information system capable of tracking the state of the ED (patients and resources) in real time and calculating the recommended decision. Moreover, unlike in other queueing contexts (e.g., call centres), patients must be reprioritised as their individual waiting times lengthen. The reasoning therefore shifts from overall system load to each patient's specific waiting time. This is the essence of dynamic prioritisation models. Finding the optimal solution becomes more complex, but Legros, Jouini and Koole (2018)[14] propose an effective uniformisation algorithm to calculate such 'waiting-time–based' policies.

These rules outperform those based only on patient counts, because they consider both acuity and the waiting time already endured by each individual. They are still imperfect, however, and other factors, such as fairness, age, sex and risk of complications, must also inform routing. Empirical analysis, supported by machine learning, can enrich the policies derived from dynamic programming and better capture the diversity of clinical situations.

Ultimately, the goal is to provide a decision-support tool which, even if not strictly optimal, improves flow management, reduces individual waiting times, and respects the specific needs of each patient. Crucially, this human–machine cooperation will only succeed if healthcare staff retain genuine responsibility and are valued for the quality of their decisions.

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[13] Puterman, M. L. (2014). *Markov Decision Processes: Discrete Stochastic Dynamic Programming.* John Wiley & Sons.
[14] Legros, B., Jouini, O., & Koole, G. (2018). A Uniformization Approach for the Dynamic Control of Queueing Systems with Abandonments. *Operations Research*, *66*(1), 200-209.

PART FOUR

STAFF TRAINING AND ITS ROLE IN FLOW OPTIMISATION

TRAINING OF CLINICAL AND NON-CLINICAL STAFF AND ITS ROLE IN FLOW OPTIMISATION

IDENTIFYING THE KEY ROLES OF CLINICAL AND NON-CLINICAL STAFF

According to a report by the Court of Auditors, in 2023, non-clinical staff accounted for 29% of personnel in French public hospitals[15]. In other words, almost one-third of employees never see patients directly, instead managing non-medical tasks that support hospital operations. These functions span a wide range of roles, all essential to clinical activity: some manage administrative tasks related to patient pathways (reception, admissions, medical secretariat), while others are responsible for hospital management (payroll, accounting, etc.). Another group is responsible for logistics, which includes catering services and the supply of materials necessary for patient care. Finally, some of these employees are technicians and maintenance workers who take care of hospital facilities. The Court of Auditors' report highlights that coordination between clinical and non-clinical functions is a key condition for smooth patient pathways. One avenue for improvement could be to increase staff versatility and efficiency. Specifically, it could be beneficial to diversify non-clinical staff profiles and train clinical staff in patient flow management policies. Doing so could reduce errors and bottlenecks in emergency departments. A TRISAN report notes that in Germany, ED congestion has been alleviated by introducing a system of primary care walk-in centres (*Bereitschaftsdienstzentrale – BDZ; Notfallpraxen*) staffed by independent physicians. These centres are located either within hospitals or nearby, allowing patients presenting to the ED for unscheduled, non-urgent care to be redirected accordingly[16]. In the UK, non-urgent patients are encouraged to use alternative urgent care services such as NHS Walk-in Centres, which provide care for less serious medical issues without the need for an appointment[17].

It is widely recognised that the public hospital system is facing a staffing crisis, due in part to low pay and notoriously difficult working conditions. According to France Travail, France's national employment agency, 99% of establishments report difficulties in recruitment[18]. Paradoxically, the solution to hospital overwork does not always lie in increasing headcount. One way to improve efficiency without increasing resources is to make appointment planning more effective by optimising time slots and anticipating disruptions on the side of doctors and clinical staff (such as lateness, delays or no-shows). At present, the appointment system is ineffective for patients, as nothing is done to plan for these unexpected circumstances[19]. Research also shows that patients are not necessarily punctual: they may arrive earlier or later than their scheduled time, or fail to attend altogether. This means that actual arrival times relative to appointments are unpredictable. One way of addressing this could be to organise patient flow according to actual waiting times rather than the number of patients in line[20].

To avoid excessive patient walk-out rates, which undermine hospital efficiency, another approach could be to take into account the risk of clinical and non-clinical staff working overtime, by optimising schedules and

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[15] Cour des comptes. (2025). Le personnel non soignant à l'hôpital public : repenser les fonctions support. https://www.ccomptes.fr/sites/default/files/2025-05/20250526-RALFSS-2025-personnel-non-soignant-hopital-public.pdf

[16] TRISAN. (2025). Les soins médicaux urgents en Allemagne. https://www.trisan.org/fileadmin/user_upload/Rettungsdienste-VF_final.pdf

[17] Schofield, A. (2025). Urgent treatment centres and walk-in centres. NHS Cheshire And Merseyside. https://www.cheshireandmerseyside.nhs.uk/your-health/helping-you-stay-well/urgent-treatment-centres-and-walk-in-centres/

[18] *« Les établissements publics de santé vont devoir engager des recrutements importants et améliorer les conditions de travail » - France Travail*. (2023). France Travail. https://www.francetravail.org/accueil/actualites/2023/les-etablissements-publics-de-sante-vont-devoir-engager-des-recrutements-importants-et-ameliorer-les-conditions-de-travail.html?type=article

[19] Legros, B. (2021). Agents' Self-Routing for Blended Operations to Balance Inbound and Outbound Services. *Production and Operations Management, 30*(10), 3599-3614.

[20] Jouini, O., Benjaafar, S., Lu, B., Li, S., & Legros, B. (2022). Appointment-driven queueing systems with non-punctual customers. *Queueing Systems*, 101(1), 1-56.

assignments. Factoring this constraint into decision-making could help reduce costs linked to workplace stress and burnout.

TARGETED TRAINING PROGRAMMES

In terms of training programmes to support non-clinical staff in improving patient flow management, several avenues can be explored.

The first could be to strengthen their basic emergency care skills through continuous training, so they can assist their doctor and nurse colleagues during periods of congestion. This would allow both clinical and non-clinical staff to share a common foundation of skills, thereby improving cooperation during busy times. A second avenue could be to improve their ability to manage stress, to ensure rational decision-making and help prevent burnout. In practice, this could take the form of scenario-based simulation workshops designed to build stress resilience and improve responsiveness during surges in patient flow. Finally, in a society where communication and information technology are central to everything, it is essential to train non-clinical staff in effective communication methods and the optimal use of IT systems. As we will see in the next section, call centres can play a key role here.

PART FIVE

THE ROLE OF CALL CENTRES IN EMERGENCY MANAGEMENT

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THE CURRENT ROLE OF CALL CENTRES

The three main emergency call centres in France are 15, the urgent medical assistance service (SAMU); 18, the fire service; and 112, the EU-wide emergency number. Their role is to act as the first point of contact for patients, conducting an initial assessment of the situation and providing immediate assistance to persons in distress. In addition, they also help to reduce pressure on emergency departments, by directing patients to the most appropriate care services.

Reconsidering the role of emergency call centres could therefore be part of the solution for optimising patient flow management in hospitals. This could involve, for example, increasing call centre capacity to reduce call waiting times and improve patient orientation, prioritising a more individualised rather than standardised approach. In this context, a key reform could be to implement policies that reserve capacity for future demand by redirecting all identified non-urgent calls to other channels or centres.

The impact of telemedicine and remote consultations on emergency department flow should not be underestimated and could be a promising area to explore further. Since the French Hospital, Patients, Health, Territories (HPST) law of 21 July 2009, telemedicine has been defined and regulated in France. Telemedicine encompasses several types of interactions: a patient may have a teleconsultation with a doctor; doctors may engage in a remote consult to agree on a diagnosis or treatment plan; a physician may interpret clinical or test results remotely or provide remote assistance to a colleague during a procedure; and a doctor at an emergency call centre can help regulate care and direct patients to the most appropriate service. According to the French Directorate for Research, Studies, Evaluation and Statistics (DREES), the number of teleconsultations carried out by private general practitioners was estimated at 9.4 million in 2021[21]. A wider adoption of this practice could generate savings through the restructuring of care and the pooling of medical expertise. More importantly, it could help to relieve pressure on public hospitals.

For the sake of comparison, Sweden has long been a European frontrunner in the adoption of telemedicine, with reimbursement for such services in place since 2016[22]. According to a report by the Swedish National Digital Health Agency, the uptake of telemedicine has been facilitated by the widespread deployment of digital tools across the healthcare system, notably the democratisation of digital IDs (e-identification) and online health records, as well as the introduction of self-service registration and payment kiosks to help alleviate pressure on emergency departments[23]. In the policy paper ‘Making health a European priority’, the Jacques Delors Institute stresses that the digitalisation of healthcare is a strategic priority at the EU level. In line with this, a European Health Data Space (EHDS) is currently being established to provide patients with straightforward and immediate access to their electronic health records in EU member states[24].

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[21] Vie Publique. (2025). La télémédecine, une solution pour faciliter l'accès aux soins ? https://www.vie-publique.fr/eclairage/18473-la-telemedecine-une-solution-pour-faciliter-lacces-aux-soins

[22] De Foucaud, I. (2019, September 10). Comment la télémédecine s’est installée dans le paysage médical en Suède. *Challenges*. https://www.challenges.fr/entreprise/sante-et-pharmacie/comment-la-telemedecine-s-est-installee-dans-le-paysage-medical-en-suede_673765

[23] E-hälsomyndigheten. (2021). Uppföljning Vision e-hälsa 2025. https://www.ehalsomyndigheten.se/globalassets/ehm/3_om-oss/rapporter/uppfoljning-vision-e-halsa-2025-rapport-avseende-2021.pdf

[24] *Making health a European priority - Jacques Delors Institute*. (2025). Jacques Delors Institute. https://institutdelors.eu/en/publications/making-health-a-european-priority/

IMPROVING COORDINATION AND INFORMATION SHARING

As discussed above, the need to share health data is very much a current priority, given that we live in a globalised society where cross-border flows of people have become a common reality. This increased population mobility requires greater cooperation between healthcare actors, both domestically and, more importantly, at the European level, specifically between pre-hospital and hospital stakeholders, as well as among pre-hospital providers themselves.

In the policy paper '*Towards a European health union*', the Jacques Delors Institute notes that the exchange of health data for healthcare and research purposes remains inadequate, despite digital tools offering enormous potential for improving patient care pathways[25]. This reality underscores the need to enhance coordination and information sharing between healthcare services. In this regard, it would be useful to streamline protocols for transferring information between call centres and EDs. Implementing integrated information systems shared across services and capable of storing, processing and disseminating data would save considerable time and help prevent overcrowding in EDs. Another technology that could help improve the flow of patients to EDs is artificial intelligence (AI), a rapidly expanding research field with significant potential in healthcare. According to the French government's official website, AI is already being used to enhance mental health services, through connected devices, chatbots and conversational agents, for instance[26]. Following the example of mental health care, a multi-channel approach could be adopted to prevent ED congestion, particularly by widening the use of instant messaging[27]. Implementing AI- or agent-powered instant chat would enable potential patients to communicate directly online with a qualified professional or digital responder, thereby avoiding unnecessary trips to the hospital for health issues that may not constitute true emergencies.

[25] *Towards a European health union - Jacques Delors Institute*. (2021). Institut Jacques Delors. https://institutdelors.eu/publications/pour-une-europe-de-la-sante/

[26] Info.gouv.fr. (2025). L'intelligence artificielle au service de la santé mentale. https://www.info.gouv.fr/actualite/lintelligence-artificielle-au-service-de-la-sante-mentale#:~:text=L'IA%20et%20les%20outils%20en%20sant%C3%A9%20mentale,-L'IA%20est&text=Ces%20outils%20recueillent%20des%20donn%C3%A9es,%C3%A9tat%20clinique%20de%20leurs%20patients

[27] Legros, B., & Jouini, O. (2019). On the scheduling of operations in a chat contact center. *European Journal of Operational Research*, *274*(1), 303-316.

PART SIX

CHALLENGES AND OUTLOOK

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APPLICABILITY OF MATHEMATICAL MODELS

Nicolas Copernicus once remarked that 'mathematics is written only for mathematicians'[28]. And this is precisely one of the discipline's weaknesses: at a certain level, it becomes a science difficult to understand for most people.

To be effective and truly influence decision-making, the solutions derived from mathematical models must be explained and understood outside the narrow confines of the stylised model in which they were developed. While a limited understanding of mathematics restricts their applicability, they should not be left as magical solutions or surprises that just happen to work without anyone actually knowing why.

It is also important to bear in mind that mathematics can only operate within a simplified frame of reality. In other words, models do not strictly reflect reality; in fact, they ignore many aspects of it. Moreover, mathematical models rely on accurate and comprehensive data. This in turn requires an effective data collection system. A single erroneous value during an initial prediction can distort parameter estimates and lead to inappropriate decisions. Finally, the real weakness of mathematical models lies in how difficult it is for them to capture certain aspects of human complexity and rare events.

INTEGRATING HUMAN AND ORGANISATIONAL FACTORS

For mathematical models to best reflect reality, they must incorporate human and organisational factors, particularly when, as in our case, the model is intended to reduce congestion in emergency departments. First, it is important to account for the negative externalities arising from hospital staff behaviour that can contribute to greater congestion. In the hospital context, this includes recognising the influence of organisational culture, which shapes staff behaviour and the dynamics of the institution as a whole. It is also essential to consider potential resistance to change, both among patients and staff, who may be reluctant to alter established work practices. In addition, the motivation of clinical staff needs to be taken into account, especially in relation to workload. A study published by the French Directorate for Research, Studies, Evaluation and Statistics (DREES) highlights the deterioration of working conditions in hospitals between 2003 and 2019. Workload in hospitals remains higher than in other sectors, with irregular hours, an intense pace, and high emotional and physical demands[29]. These difficult conditions increase the risk of distress among healthcare staff and ultimately undermine the attractiveness of the profession itself. Another DREES study, published in 2023, reports a higher prevalence of depression and anxiety linked to these working conditions. According to the study, in 2021, 41% of hospital staff displayed symptoms of mild to severe depression, versus 33% among the overall working population[30].

Next, it is important to be aware of the negative externalities that occur when a patient enters a system – in our case, the emergency department. Two approaches exist to raise awareness of this issue: binding and non-binding

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[28] *Nicolas Copernic-Les mathématiques ne sont écrites que pour les*. (2025). Evene.fr. http://evene.lefigaro.fr/citation/mathematiques-ecrites-mathematiciens-69259.php

[29] Vie Publique. (2021). Hôpital : des conditions de travail de plus en plus difficiles. https://www.vie-publique.fr/en-bref/282444-hopital-des-conditions-de-travail-de-plus-en-plus-difficiles

[30] *À l'hôpital, une prévalence accrue de la dépression et de l'anxiété due notamment aux conditions de travail | Direction de la recherche, des études, de l'évaluation et des statistiques*. (2023). https://drees.solidarites-sante.gouv.fr/publications-communique-de-presse/etudes-et-resultats/lhopital-une-prevalence-accrue-de-la

incentives[31]. The first strategy involves controlling admissions or implementing symbolic fees (as mentioned above) to reduce congestion. A key drawback of this approach in our context is that emergency care is a public service, making this strategy potentially difficult to justify from an ethical perspective. The second strategy is the non-binding alternative. Its aim is to help patients understand the negative externality created when they decide to join the queue. In conditions of congestion, this decision can place undue strain on hospital resources. One alternative could be to educate patients during their waiting time through posters at the ED entrance, following a model similar to road safety campaigns displayed along roadsides. This could be extended beyond the hospital itself, through media campaigns online, on social media, or even on television. Another solution could be to implement an online reservation system where patients are informed of the additional waiting time caused by their arrival. The advantage of this non-binding strategy is that it does not involve economic incentives or any approach that restricts individual choice. In the United States, some healthcare groups allow patients to book appointments online for non-critical emergencies, enabling them to wait at home rather than in a waiting room, thereby helping to reduce queues[32]. A similar strategy has been implemented in Quebec, where, to discourage residents from attending overcrowded EDs, the Ministry of Health provides a website displaying up-to-date hospital waiting times[33].

FUTURE POSSIBILITIES

Below is a summary of potential courses of action to help improve patient flow in France's emergency departments:

1. **Use new digital technologies:**
- **Encourage human–machine cooperation** by having AI perform an automatic pre-triage that redirects patients before they present at the ED, smooths patient flow, improves the accuracy of predictions, and reduces the impact of risk aversion.
- **Expand the use of telemedicine and digital health solutions** by introducing self-service registration and payment kiosks.
- **Use digital twins to dynamically test organisational and strategic changes** and evaluate their hypothetical impact on hospital performance.

2. **Train hospital staff:**
- **Increase the versatility and efficiency of clinical and non-clinical staff by training them** to optimise patient flow and length of stay.
- **Develop a continuing professional development (CPD) system for training in emergency medical skills** to support clinical staff during periods of congestion. This would create shared competencies among all staff, improving cooperation.
- **Improve stress management through scenario-based training.** The development of interactive simulation platforms for training and planning could also be considered.

3. **Reorganise:**
- **Implement a system to triage patients at the ED entrance.** However, it should be noted that a key limitation of this approach is distinguishing between a patient's actual state and their perceived state.
- **Facilitate the construction of local hospitals providing basic care alongside referral hospitals equipped with specialised facilities and advanced care.**
- **Factor into the decision-making process the risk of staff attrition related to stress and burnout.** To mitigate these, optimise schedules and assignments to prevent unplanned overtime for clinical staff.

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[31] Legros, Benjamin and van Leeuwaarden, Johan, Wait Externality Awareness for Socially Responsible Queueing (March 17, 2025). Available at SSRN: https://ssrn.com/abstract=5182011 or http://dx.doi.org/10.2139/ssrn.5182011

[32] Aux Etats-Unis, les patients peuvent prendre rendez-vous pour aller aux urgences. (2022, December 13). What's Up Doc. https://www.whatsupdoc-lemag.fr/article/aux-etats-unis-les-patients-peuvent-prendre-rendez-vous-pour-aller-aux-urgences

[33] Info, R. (2023, January 31). Urgences : un nouveau site répertorie les temps d'attente au Québec. *Radio-Canada*. https://ici.radio-canada.ca/nouvelle/1952273/sante-dube-hopital-soins-urgence-temps-attente-site

- **Facilitate information transfer protocols between call centres and the ED** through an integrated information system.

4. Introduce binding and non-binding incentives:

- **Implement binding incentives, such as symbolic admission fees**, to discourage non-essential visits.
- **Implement non-binding incentives** to help patients understand the negative externality created when they decide to join the queue. In conditions of congestion, this decision can place undue strain on hospital resources. One approach could be to **raise patient awareness through poster campaigns displayed at ED entrances.** A second could involve **media campaigns.** A third could be to **set up an online booking system** informing patients of the additional waiting time generated by their arrival.

CONCLUSION

In conclusion, this policy paper has sought to analyse how mathematical approaches can inform and improve the management of queues in emergency departments, taking into account factors such as risk, prioritisation, staffing, digital tools, organisational restructuring, and call centres. We have put forward a series of recommendations for hospital administrators and policymakers, emphasising the importance of an interdisciplinary approach combining medical, operational, and mathematical expertise to address the future challenges facing emergency services.

AUTHORS

Benjamin Legros, Professor of Operations Management at SKEMA Business School (Centre for Analytics & Management Science, Grand Paris campus). His research focuses on the optimisation of real-time decision-making in stochastic systems (queues, MDPs) with applications in contact centres, transport, and healthcare. He holds a PhD in Industrial Engineering from CentraleSupélec (2013) and an accreditation to supervise research (HDR, 2024). His work has been published in journals including *Production and Operations Management*, *Operations Research*, and *Manufacturing & Service Operations Management*.

Frédérique Vidal, Director of Development at SKEMA Publika and Director of Strategy and Scientific Impact at SKEMA Business School. Full Professor of Biology, President of the University of Nice Sophia Antipolis from 2012 to 2017, and subsequently Minister of Higher Education, Research and Innovation in the Philippe and Castex governments from 2017 to 2022. She served as special advisor to the President of EFMD and is currently also the Permanent Representative of the Principality of Monaco to the United Nations Environment Programme and the Whaling Commission.

Sean Scull, Think Tank Project Manager. He holds a degree in Political Science with a specialisation in International Relations from the University of Gothenburg, and a Master's degree in International Politics with a focus on Anglophone politics from the University of Toulon. Sean has lived and worked in Sweden and the United States of America.

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The authors' biographies are available on https://publika.skema.edu/

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