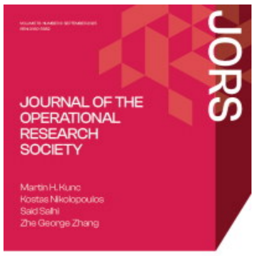

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A methodological framework combining a facilitated and expert mode to extend the simulation model lifetime: a case study of an ambulance service

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ABSTRACT
Typically, simulation studies conclude after one modelling cycle, producing a model that addresses the objectives defined at the outset. Healthcare settings are complex and volatile, which means that simulation models and their findings can quickly become obsolete as the real system changes. This paper presents a real-life case study of a regional Ambulance Service Trust where simulation is used to evaluate the impact of changes to ambulance services on their efficiency. Our findings show that alternative ambulance- and community-based services, especially those placed early in the call cycle, can reduce avoidable conveyances to the Emergency Department. Drawing on our experience, this study proposes a methodological framework that prescribes a practice of moving from a facilitated mode in a first cycle to an expert mode in the second cycle to make necessary adjustments to the model. The paper discusses the benefits achieved in securing stakeholder buy-in by adopting a first facilitated modelling cycle and the saved time and effort by adopting an expert mode in the second cycle to extend model lifetime. Considering that facilitated modelling is time and resource-intensive, implications for simulation model development theory and practice are provided.

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Healthcare; simulation; OR practice; facilitated modelling; stakeholder engagement; ambulance service

1. Introduction

Healthcare simulation studies often face challenges in achieving implementation (Beliën et al., 2025; Brailsford et al., 2009; Brailsford & Vissers, 2011; Carter & Busby, 2023; Fone et al., 2003; Harper & Pitt, 2004; Jun et al., 1999; Lamé et al., 2022; Lowery et al., 1994; Young et al., 2009). Participatory and facilitated simulation offers an alternative solution that enhances stakeholder involvement, ensuring that simulation models are relevant and align to stakeholders' priorities in real life settings (Kotiadis & Tako, 2018; Lamé et al., 2023; Tako & Kotiadis, 2015), but it can be resource and time intensive.

Moreover, healthcare environments are dynamic and volatile, with frequent changes in practices, key performance indicators (KPIs) and stakeholder needs (Tako & Robinson, 2015). This means that the models developed could become quickly obsolete. A similar situation arose in the current study, where soon after a simulation model of an ambulance service was developed, changes to the classification of patient calls and the reporting of response time targets were introduced nationally in the UK. These changes raised concerns about the relevance of the model results, leading to a second modelling cycle to modify the originally developed model.

Typically, simulation studies follow a single modelling cycle, progressing through key stages: problem exploration, conceptual modelling, model building, experimentation, and implementation, often iterating between stages (Brooks & Wang, 2015; Tako, 2015; Willemain, 1995). However, as Pidd (1998) notes, additional modelling cycles may be necessary if new problems emerge or if further refinements are required during model implementation.

An example of extending a model's lifecycle can be found in Jones et al. (2022), who describe the development of a simulation model of a high speed railway company, Eurostar International Limited. Their study involved two separate facilitated modelling cycles, each engaging different stakeholder groups. The need for the second cycle arose due to additional model requirements by a new stakeholder group, illustrating how simulation models can be adapted to accommodate evolving stakeholder needs.

Similarly, this study reports an example of extending the lifetime of a simulation model in two model development cycles, with the difference that

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an initial facilitated mode cycle is followed by an expert mode cycle. In a facilitated mode analysts work jointly with a stakeholder group in a workshop environment to co-create models that are aligned with and relevant to real-world needs (Kotiadis et al., 2014; Tako & Kotiadis, 2015). In contrast, an expert mode is primarily modeller-focused. The modeller creates a model based on their understanding of the problem and subsequently hands over the model and/or recommendations to stakeholders.

This paper presents a novel simulation study of a real-life regional Ambulance Service Trust (AS Trust) concerned with the ongoing challenge of constrained capacity faced by emergency services in the UK and internationally. Ambulance services are under increasing pressure from high patient demand coupled with limited resources, which subsequently leads to delays in responding to patient calls and reduced quality of service delivery. These issues intensify during the winter months, due to overcrowded Emergency Departments (ED), where ambulances are frequently delayed while waiting to hand over patients (Kirkland & Titheradge, 2020; Roberts, 2022; Young, 2020).

Much of existing literature focuses on improving ambulance service efficiency through resource optimisation, particularly in dispatch and vehicle location strategies. In contrast, our model explores the potential efficiencies that can be gained from introducing alternative ambulance- and community-based services within a regional AS Trust. To our knowledge, this is a novel study that considers the operational efficiencies that can be achieved, by intervening in the ambulance call cycle through the introduction of new services. Specifically, it considers how avoidable ambulance transfers to ED can be reduced and response times improved.

Moreover, the current study encountered challenges due to operational changes introduced across UK ambulance services nationally during the research period. Initially launched in 2016, the project adopted a fully facilitated approach, involving four stakeholder workshops based on the PartiSim framework (Tako & Kotiadis, 2015). However, a year after (2017), changes to patient calls classification and reporting of patient response times meant that the model was obsolete. In response, a second modelling cycle was undertaken in expert mode, utilising the stakeholder insights gained in the first cycle.

Drawing on our experience, this study proposes a methodological framework for extending the lifetime of simulations in two model development cycles, an initial facilitated mode followed by a second expert mode cycle. To the best of our knowledge, this approach has not been previously reported in the literature and it warrants consideration, as it offers a promising avenue for improving the efficiency of the modelling process, when a need to extend the model lifetime arises.

This study contributes to healthcare modelling literature in three main ways. First, it introduces a novel two-cycle methodological framework that extends the lifetime of simulation models. By combining a first facilitated-mode cycle with a second expert-mode cycle, the approach accommodates changes to healthcare policies and system processes to be embedded, without discarding the original model. Second, it considers the efficiency of the modelling process, retaining the benefits of stakeholder engagement while reducing the time and resource demands typically associated with full-scale facilitation in subsequent cycles. Third, the paper presents a new case study focused on operational efficiencies within ambulance services. Specifically, it examines how alternative services can reduce avoidable conveyance to Emergency Departments (EDs), an area that is little explored in the literature, as existing work has focused primarily on optimisation of ambulance dispatch and location strategies. The findings of this study are transferable to other regional AS Trusts and relevant to managers and practitioners seeking to gain evidence-based improvements in the ambulance service call cycle.

The paper is structured as follows. Section 2 reviews the relevant literature on healthcare and emergency services modelling, followed by an overview of the model development process and stakeholder engagement in facilitated modelling. Section 3 provides an overview of the ambulance case study setting, followed by section 4, which outlines the methodological approach and analysis undertaken across the two model development cycles. Section 5 discusses the methodological framework, the practical implications, study limitations and directions for future research. The paper ends with conclusions.

2. Background literature

2.1. Simulation modelling of emergency and ambulance services

Simulation can be effectively used to represent the randomness and flow of patients in emergency care systems (Aboueljinane & Frichi, 2022; Brailsford et al., 2009; Ortíz-Barrios & Alfaro-Saíz, 2020; Pitt et al., 2016; Roy et al., 2021). Emergency services face critical challenges due to the unpredictable nature of demand, often requiring immediate response to patients' needs. Patients with urgent care needs may receive care either by the ambulance, a pre-hospital care unit or at the hospital emergency department (ED). These services face further challenges due to the rising demand and costs of care and the rising trend of elderly population over the last two decades, with numbers expected to increase further in the future (Kirkland & Titheradge, 2020; Roberts, 2022; Young, 2020). Most studies evaluating urgent and emergency care services focus primarily on EDs (Bowers et al., 2009; Bowers & Mould, 2013; Brailsford et al., 2004, 2009; Fletcher et al., 2007; Gul & Guneri, 2015; Günal & Pidd, 2009; Pitt et al., 2016; Roy et al., 2021; Salmon et al., 2018; Uriarte et al., 2017; Vile et al., 2017; Young et al., 2009).

Gul and Guneri (2015) note two types of interventions adopted in the emergency services literature, changes to patient flows through service redesign to achieve more efficient use of resources within the ED unit (Mohiuddin et al., 2017; Paul et al., 2010), while others explore changes to patient admission policies into ED, for example patient streaming before arriving to ED, diversion to other services away from ED (Squires et al., 2023), reduction in ambulance conveyance rates (Vile et al., 2017) or ambulance diversion to other less overcrowded hospitals (Kao et al., 2015; Lin et al., 2015; Ramirez et al., 2009).

Other studies develop models that combine pre-hospital services (offered by ambulances) and emergency services (offered in hospital) to explore resource planning and ambulance relocation decisions (Aboueljinane & Frichi, 2022; Panayides et al., 2023; Tedesco et al., 2024). These studies test amongst others how ambulance patient routing strategies can achieve faster response times and they are concerned with capacity planning at overall emergency care system level. Others, Bovim et al. (2023) model the ambulance service in conjunction with the emergency department, to estimate the number of ambulances needed to respond to patient calls, accounting for additional ambulance and medical staff needed for COVID-patients during the pandemic in a region of Norway. Their analysis aims to maintain ambulance response times comparable to pre-pandemic levels.

While previous studies have explored the impact of ambulance services within the wider emergency services system, there is merit in considering the operational efficiencies that can be achieved at ambulance service level. There is already a large number of studies that consider the operational efficiency of the ambulance service focused primarily on ambulance dispatch and location decisions (Aringhieri et al., 2017; Brotcorne et al., 2003). These studies aim to optimise ambulance dispatch and location strategies with the view to improving ambulance response times (Aboueljinane & Frichi, 2022; Bélanger et al., 2020; Enayati et al., 2019; Jagtenberg et al., 2020). Authors use discrete-event simulation (Ingolfsson et al., 2003) or a combination of simulation and optimisation to maximise the efficiency of ambulance vehicle configuration (Aboueljinane & Frichi, 2022; Bélanger et al., 2020; Enayati et al., 2018; Essus et al., 2024; Frichi et al., 2022; Golabian et al., 2021; Grot, 2024; Lam et al., 2015).

Models exploring ambulance dispatch strategies are primarily region-specific, some examples include the Tainan's region in Taiwan (Wu & Hwang, 2009), Belo Horizonte in Brazil (Silva & Pinto, 2010), a southeast district in Paris (Aboueljinane et al., 2014). Pinto et al. (2015) develop a generic ambulance model that includes the three main service components, call generation, ambulance dispatch and ambulance journey, but it predates the changes introduced to the ambulance pathway. Models using dynamic ambulance reallocation and dispatch strategies have become more popular recently due to advancements in Global Positioning System (GPS) technology and in computing systems (Enayati et al., 2018; Lam et al., 2015). Lim et al. (2011) review the different dynamic dispatch policies used in the literature and compare their advantages and disadvantages. A recent study by Paz et al. (2022) extends existing dispatch policies by incorporating volunteer citizens based in the community to respond to an emergency alongside ambulance vehicles and show that it can positively contribute to lower response times. Essus et al. (2024) consider the adoption of outsourced riding services for minor emergencies.

Despite the growing interest in optimising ambulance service operations, the potential for improving patient flows and the operational efficiency within the ambulance service pathway has been little explored. Existing studies have primarily focused on policies such as deployment of early responder vehicles, alongside ambulance vehicles and their impact on response times (Stein et al., 2015), staffing strategies for emergency call centres (Buuren et al., 2017) and ambulance fleet management (Kergosien et al., 2015, 2023). However, to the best of our knowledge, these models do not explicitly examine how modifications to patient flows and services offered within the ambulance service pathway influence operational efficiency and patient wating times. Tako et al. (2020) used an adapted version of the ambulance service model presented in this paper to explore differences in learning outcomes between students groups when using simplified and more complex models. The current paper provides a detailed account of the model developed, with a particular focus on the modelling methodology adopted to support stakeholder engagement and model adaptation.

2.2. Simulation in healthcare and stakeholder engagement

Problems in healthcare are complex due to the interconnected nature of health services, often involving interactions with multiple stakeholders who have different perspectives and objectives distributed power and knowledge across the system (Clarkson et al., 2018; Klein & Young, 2015; Lamé & Simmons, 2020). As a result, studies focusing only on the quantitative findings may not achieve their full potential, as important aspects about the system can be overlooked (Robinson, 2014; Tako & Robinson, 2015). Emergency care and ambulance services are no exception (Mohiuddin et al., 2017).

A challenge often noted is the lack of wider application of healthcare modelling and their findings in practice (Beliën et al., 2025; Brailsford, 2005; Carter & Busby, 2023; Fone et al., 2003). Lamé et al. (2022) note the limited implementation of healthcare OR studies continues to be a concern, similar to the findings of a systematic review more than 15 years ago, which found that only 5.3% of articles reviewed reported implementation (Brailsford et al., 2009). Involving stakeholders in the modelling process can improve the chances of study success (Bowers et al., 2009; Brailsford & Vissers, 2011; Eldabi et al., 2007; Fone et al., 2003; Günal & Pidd, 2009; Jun et al., 1999; Lowery et al., 1994; Vile et al., 2017; Wilson, 1981; Young et al., 2009). A systematic literature review focused on simulation of the ED indicates that out of the 21 papers identified, only half reported some level of stakeholder involvement (Mohiuddin et al., 2017). Even in the cases reported, there is limited detail about the extent of engagement with the stakeholder group or the modelling process followed.

Facilitated simulation involves co-developing models and subsequent solutions working collaboratively in workshops with a group of stakeholders (Kotiadis et al., 2014; Kotiadis & Tako, 2018; Tako & Kotiadis, 2015). Over the last decade facilitated modelling has gained momentum in healthcare (Kotiadis & Tako, 2018), but also in other domains such as transport (Jones et al., 2022). Involving stakeholders in the modelling process in a structured way through workshops offers stakeholders a better understanding of their organisational issues and the opportunity to inform action for change in their system (Kotiadis et al., 2014; Tako & Kotiadis, 2015). This in turn, enhances stakeholders' confidence in the findings, their perceived accuracy of the model and their commitment to implementation (Karnon, 2003; Harper et al., 2021).

Key studies that report use of facilitated modelling include the SimLean approach (Robinson et al., 2014) which combines the use of simulation models and lean processes. PartiSim is a multimethodology framework that interweaves hard and soft OR approaches, inspired from Soft Systems Methodology to support stakeholder interaction through a set of dedicated workshops, activities and tools (Tako & Kotiadis, 2015). Others, such as Baril et al. (2016) adopt a facilitated simulation approach to support a kaizen event aimed at reducing delays. Proudlove et al. (2017) and Onggo et al. (2018) consider the use of the BPMN standard and extension to enable live model coding in a facilitated workshop with stakeholders, with some limited success due to data and conceptual complexity encountered. More recently, Jones et al. (2022) report applying facilitated hybrid simulation involving stakeholders in the public transport sector. Harper and Mustafee (2023) follow a similar model development approach to PartiSim to co-produce the design requirements in developing a real-time simulation model of an emergency department.

2.3. The simulation model development process

Various authors have put forward modelling frameworks that describe the activities undertaken during the simulation model development process (Arthur & Nance, 2007; Balci, 2012; Banks et al., 2010; Kreutzer, 1986; Law (2024; Nance, 1994; Sargent, 2013; Shannon, 1981), Pidd, 1998; Robinson, 2014). While the number of steps and detail of prescribed activities vary between models, the process is generally similar (Jones et al., 2022; Robinson, 2014; Sargent, 2013; Tako, 2015). For example, Kreutzer (1986) describes the "life cycle of a simulation project" in a sequence of nine steps, while Pidd (1998) describes it as a three stage process starting from problem structuring, modelling, then leading to implementation. Robinson (2014) on the other hand includes four stages. This paper adopts the Robinson 2014 framework as it entails the main modelling activities common in most frameworks, including: conceptual modelling, model coding, experimentation and implementation. These core modelling activities also form the basis of facilitated modelling frameworks that outline the steps followed in engaging stakeholders during simulation model development (Kotiadis & Tako, 2018; Tako & Kotiadis, 2015). In addition these frameworks consider the structure and form of stakeholder engagement. The PartiSim approach proposed by Tako and Kotiadis (2015) is adopted in the first modelling cycle of this study.

Soon after the first modelling cycle was completed, national changes to the measurement of key response time targets across ambulance services, meant that the model results did not align anymore to reality, raising concerns about its relevance for decision-making by the AS Trust. As Pidd (1998) notes, evolving model requirements or changes in priorities, can lead either to early project termination or the initiation of a new modelling cycle. In this case, a second cycle took place to adapt the model to the new real life context. This could arise at any stage of a modelling project, particularly during implementation, when further requirements often emerge.

Jones et al. (2022) report a similar situation when building a simulation model of Eurostar's St Pancras International Station, where a different group of stakeholders asked for additional changes to the simulation model developed at the end of the study. To the best of our knowledge, this is the only study that proposes a new modelling framework consisting of two modelling cycles. Jones et al. (2022) undertake two modelling cycles in response to the need identified to extend the originally developed model. Each cycle involved one facilitated workshop to agree the conceptual model with two separate stakeholder groups. This was necessary as the changes to the model needed to be agreed upon with the stakeholders. A similar sequence of activities was followed in both modelling cycles and the authors report spending a significant effort in designing and organising the two workshops, pointing out to the challenges of organising workshops with a group of stakeholders who need to take out time of their busy work schedules.

The study presented in this paper offers a new modelling framework that leverages value from meaningful engagement with a group of stakeholders at a first modelling cycle, considering that the organisation of facilitated workshops is resource and time intensive, but also that some models may run into the risk of becoming obsolete. Similarly to the study by Jones et al. (2022), changes to the ambulance call model developed were needed to adapt the calculation of ambulance response time targets, but no significant changes to the model structure and scenarios tested were needed. Hence this paper puts forward an alternative framework that introduces a second modelling cycle undertaken in an expert mode i.e. without workshops, after a first facilitated mode cycle. To our knowledge, such a modelling framework has not been reported in the literature so far.

2.4. Summary of the gap in existing simulation literature

In summary, the review of existing literature above has identified two main gaps. First, models of emergency services have not explored changes in patient flows within the ambulance patient pathway and how these could impact patient waiting times and lead to operational efficiencies at ambulance service level. Second, few studies discuss modifications made to the model at the end of a modelling study. An exception is the study of Jones et al. (2022) who report undertaking a second modelling cycle to incorporate further changes to the model, while working with a different stakeholder group.

Changes introduced by the Government in 2017 specifically to the way key ambulance response times are calculated meant that further changes to the model were required. Under these circumstances, the simulation could be considered "wrong" and so disregarded and not used. Indeed, Tsioptsias et al. (2023) undertook an empirical study of "wrong" models by interviewing modellers and found that a significant proportion (44%) of models considered "wrong" are not further used, while the remaining 56% had some practical application.

To avoid discarding the model developed in the first facilitated-mode cycle, it was instead modified in a second expert-mode cycle, to reflect contextual changes to response time targets, introduced to the ambulance service pathway.

3. Overview of the ambulance service setting

This section presents the setting of the ambulance study. Demand for emergency services has increased over the years and ambulance trusts face pressures to provide a timely response to an increasing volume of calls, especially at peak times in the winter months (Clarey et al., 2014; Enayati et al., 2018; Snooks et al., 2019). In addition, ambulances experience delays in handing over patients to overcrowded emergency departments in hospitals, which impacts their response times even more (Kirkland & Titheradge, 2020; Roberts, 2022; Young, 2020).

The role of ambulance services and the way they operate has evolved over time. Paramedics are now equipped with a wider range of skills which means they can make clinical decisions and offer a wider range of clinical interventions to patients, such as assess, treat or refer a patient to another non-hospital service (Heath & Radcliffe, 2007). A wider government initiative to reduce the number of patients admitted to hospital Emergency Departments (ED) has seen the introduction of community-based healthcare services and facilities. A review of the ambulance service took place in 2013 which led to a service redesign of the ambulance call cycle (Keogh, 2013). It introduced alternative options of care, to include treatment over the phone (hear and treat), conveyance to community based services (alternative pathways) or paramedics treating patients on the scene (see and treat), in an effort to reduce patient transport to the ED in hospital (Keogh, 2013; NHS England, 2013, 2017c, National Audit Office, 2017, 2018; Palmer et al., 2018). This was initially rolled out in few selected AS trusts in the UK in 2015 on a pilot basis, of which the regional AS trust we worked with was one.

A description of the new services introduced is provided below:

- *Hear and treat (H&T)* – patients with minor health issues are offered advice over the phone or directed to appropriate non-hospital services. This role was fulfilled by a newly introduced resource called Clinical Assessment Team (CAT), consisting of paramedics and/or nurses.
- *See and treat (S&T).* Paramedics and/or technicians going out to patients in an ambulance vehicle treat patients at the scene;
- *Alternative pathways (ALT).* Patients are transported to alternative community based settings outside hospital, such as dedicated ambulatory centres or community urgent care services (Blodgett et al., 2021; Steventon et al., 2018).

Regional ambulance teams had limited prior understanding of the expected impact of implementing these service changes on their operational performance. A simulation model was developed to help the ambulance staff and paramedics understand the impact of service redesign changes to the flow of patient calls on service performance.

The regional AS Trust we worked with provides services to a population of almost 5 million people, and it is split into five different divisions. The Trust has over 3,000 employees across the region, based at over 60 locations, with two Emergency Operation Centres. It operates a fleet of over 500 vehicles, which consist of emergency ambulances, fast response cars, specialised vehicles and patient transport vehicles and it receives on average over 2,500 calls daily.

The Ambulance Service (AS) Trust was interested to understand how the changes introduced can improve its efficiency and ultimately the extent they lead to a reduction in patient conveyance rates to the ED (Coster et al., 2019; Limb, 2018; NHS England, 2017a; Noble et al., 2022).

The model developed represents the flow of patient calls at ambulance level from an operational perspective. Decisions on vehicle location and optimisation are not within the scope of the study, nor the geographical location of incoming calls, instead the model takes a high level view of service flows and their impact on performance targets. To our knowledge, this study is the first to consider the effect of the new services on the operational efficiency of the ambulance services' call cycle.

Soon after the completion of the study, a new Ambulance Response Programme (ARP) was introduced in 2017 nationally across all ambulance services, which included changes to the classification of patient call categories and reporting of response

Table 1. Ambulance response time target changes by call category, showing the old standard and the new standard introduced in 2017.

Old Ambulance Service standard (Model 1)			New Standard (2017)		
Code	Type of call	Standard	Code	Type of call	New Standard
Red Calls	Emergency calls: includes patients with breathing difficulties or experiencing a heart attack. 2 categories: Red1 and Red2.	Same standard for Red 1 & 2. 75% calls responded to within 8 min., Called **Red8** in this study, based on the 8-min target. 95% calls conveyed to hospital within 19 min. Called **Red19** in this study, based on this target.	C1	Calls for life-threatening injuries or illnesses. Need immediate treatment on the scene.	Average response time within 7 min. 90% of calls receive treatment within 15 min.
Green	Non-life threatening calls. 4 categories: Green1, 2, 3, 4.These are combined into one category in this study for simplicity.	No national set targets, varying local targets. For the AS trust in this study, they were: 85% of Green ambulance calls should result in an emergency response arriving within 20 min for Green1 and 2, 30 min for Green 3 and 60 min for Green 4. In this study all 4 categories are combined into one with an overall target of 30 min, hence called **Green30**	C2	Emergency calls	Average response time within 18 min 90% of calls receive treatment within 40 min
			C3	Urgent calls	No average response time standard. 90% of calls receive treatment within 120 min.
			C4	Less urgent calls. Patients may receive advice over the telephone or referred to another service such as a GP or pharmacist.	No average response time standard target. 90% of calls receive treatment within 180 min.

time targets (now called standards), following a review undertaken by the University of Sheffield (Knowles et al., 2020; NHS England, 2017a, NHS England, 2017b, Turner & Jacques, 2018; Turner et al., 2017). The new ARP allows more time for the call handlers to judge the patients' condition, aimed to improve the accuracy of decision making in allocating the most appropriate response. The two main Red and Green patient categories were replaced by Category 1, Category 2, Category 3 and Category 4 (C1, C2, C3, C4) which represent life-threatening, emergency, urgent and less urgent calls, accordingly. In addition, specific standards related to each call category are used to assess response times performance, as outlined in Table 1. The new C1 calls are prioritised and assigned a faster response time target (standard) of seven minutes instead of eight. For all other call categories (C2, C3 and C4), additional triage time was introduced allowing call handlers up to 240 s (4 min) to assess a patient's condition, an increase from the original 60 s.

The changes introduced meant that the simulation model previously developed in 2016 was not anymore relevant. This led to a second modelling cycle to modify the originally developed model to reflect these changes. Next, our methodological approach and an overview of the two model cycles is presented.

4. Methodological approach and analysis

The study presented in this paper was completed in two modelling cycles. Figure 1 provides an overview of the two simulation modelling cycles undertaken. Both cycles follow the sequence of modelling activities suggested by Robinson (2014). The first cycle

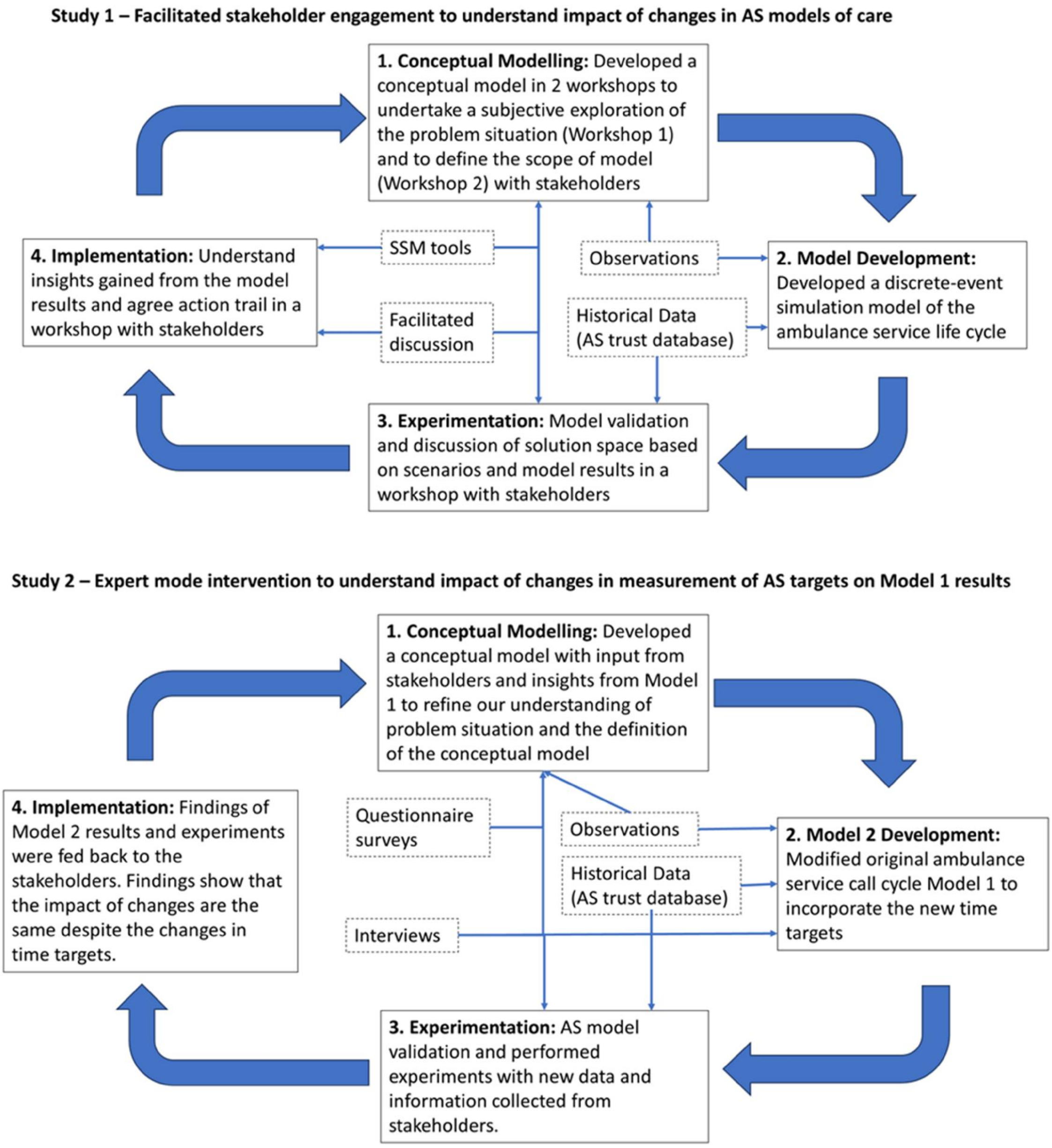

Figure 1. Overview of study methodology showing the sequence of modelling activities undertaken in the first (facilitated mode) and second (expert mode) modelling cycle.

was undertaken in a facilitated mode, adopting the PartiSim framework (Kotiadis & Tako, 2018; Tako & Kotiadis, 2015). The simulation model was co-developed in workshops with ambulance service stakeholders and then used to understand the impact of the changes to their service collaboratively.

While the stakeholders found the findings of the study highly relevant, soon after the completion of the first study, changes to the calculation of response time targets were implemented in ambulance services across the UK, and in the AS Trust this study was based on, which meant that the results of the simulation model did not correspond to real life performance indicators. This led to another cycle of model development undertaken in an expert mode to adapt the originally developed model and to experiment with using the new ambulance response targets. In the second modelling cycle, selective one-to-one input from ambulance service stakeholders was adopted to adapt the model, instead of holding facilitated workshops with the whole stakeholder group.

4.1. Modelling cycle 1

Four facilitated workshops with the ambulance stakeholder group took place. An overview of the four workshops and relevant aims is provided in Table 2. The workshops were highly interactive and structured around the prescribed activities outlined in the PartiSim framework (Tako & Kotiadis, 2015).

Workshop participants were chosen after an initial stakeholder roles analysis as outlined in Table 3. The Strategic Innovation Programmes Manager, who initiated the study and offered support throughout the study, naturally fitted the project champion role. Participation in workshops was discussed with the Strategic Innovation Programmes Manager and Clinical Quality Manager. As managers they felt their presence may inhibit the flow of conversations at the workshops, so they did not attend the workshops. It was agreed that only clinical team mentors and frontline paramedics, who are most knowledgeable of the overall ambulance call cycle, would be invited to attend the workshops.

The modeller undertook on-site observations by going on ambulance ride-outs, visiting the call handlers and the CAT intervention team in the control room at the head office. At these visits, issues related to the high number of inappropriate calls received by the AS and the organisation's target-driven culture, widely known of UK's NHS organisations were noted (Günal & Pidd, 2009). They also helped the modeller to build a rapport with the stakeholders before the workshops took place. Next, a brief overview of the modelling activities undertaken in this cycle is provided.

4.1.1. Modelling stage 1: Conceptual modelling

Two workshops were held with seven participants, four Clinical Team Mentors (CTMs) and three paramedics, to define the conceptual model. The first workshop aimed to establish a high-level understanding of the issues faced by the ambulance service and to identify potential improvements, from the participants' perspective. The second workshop took place one week after and its aim was to further define the model scope and the simulation study objectives. The aims of the workshop were to:

- Discuss model inputs, i.e., changes to be tested in the model,
- Identify and rate model outputs (performance measures) by importance and
- co-produce the process flow diagram.

Table 2. Overview of the workshops for the first modelling cycle.

Workshop	Workshop title	Aim	Modelling Stage
1	Define the system	To define the ambulance service system of interest and to gain a deeper understanding of issues faced	Conceptual modelling (1)
2	Design model scope	To design the conceptual model and define the modelling objectives	Conceptual modelling (1)
3	Experiment with the model	To validate the model and to evaluate the scenarios	Experimentation (3)
4	Implementing Solution	To identify the risks of the preferred scenarios and develop an action plan	Implementation (4)

Table 3. Key stakeholder team roles based on (Tako & Kotiadis, 2015) and nature of engagement in the study.

Stakeholder Team Roles	Stakeholder	Engagement
Project Champion	Strategic Innovation Programmes Manager	Yes (outside workshops)
Key Stakeholders	Strategic Innovation Programmes Manager	Yes (outside workshops)
	Clinical Quality Manager	NO
Other Stakeholders	Clinical Assessment Team (CAT)	NO
	Call handlers	NO
	Performance Information Analysts	Yes (outside workshops)
	Clinical Team Mentors (CTMs)	Yes (at workshops)
	Frontline paramedics	Yes (at workshops)

The overall model objective as agreed with the stakeholder group is to assess the impact of increasing the provision of new services on the ambulance response times and conveyance rates to ED in line with the first set of changes introduced in 2015. These include increases to the following:

1. the proportion of hear and treat (H&T) services offered by the Clinical Assessment Team (CAT),
2. the proportion of see and treat (S&T) services to treat patients on the scene,
3. the proportion of conveyances to alternative health care providers, such as Urgent Care Centre.

In line with the model objectives agreed with the stakeholder group, the model inputs and changes to be introduced in the input variables were discussed. These informed the scenarios to be tested. The changes suggested are based on the stakeholders' prior knowledge of the ambulance service, who believed that there was potential for re-routeing more calls for CAT Hear & Treat intervention (Scenario 1), See & Treat on the scene (Scenario 2) and Alternative to ED routes (Scenario 3) to achieve further efficiencies in their system.

Eight performance measures for the evaluation of the service were also agreed with the stakeholder team. These included:

- response time targets in line with those used at the time i.e., the percentage of red and green calls responded to within target;
- number of patient cases by pathway, including those conveyed to ED, to Alternative care providers, treated at the scene (See & treat) and Hear & treat (H&T) patients advised over the phone by the Clinical Assessment Team (CAT);
- non-conveyance vs Conveyance (NC: C) ratio to capture the effectiveness of the changes introduced as a percentage of patients conveyed to ED vs those not conveyed. The latter includes patients offered See & Treat, clinical referral to a GP or local health provider and Hear & treat patients.

The scenarios by level of change for each input parameter and the performance measures agreed with the stakeholder group are listed in Table 4 below. The four most important criteria as ranked by the stakeholders (Hear & Treat, Alternative conveyance, See & Treat and Non-conveyance vs conveyance ratio) are displayed in bold, as they are considered more representative of patient outcomes. This underlines the importance placed on the new services offered by the AS Trust. Interestingly, conveyance to ED, the Red19, Red8 and Green30 time targets were considered less important by the stakeholders.

Scenario 1, relates to the first study objective of increasing H&T services. Based on our data analysis, it was found that 23% (2,211 out of the 9,807) of cases were not conveyed, which meant that these cases could have been potentially dealt with over the phone. Therefore, the baseline CAT H&T figure of 64% was increased to: 74%, 79% and 84%, representing at most a 20% increase to ensure this was a realistic increase. Scenario 2 relates to the second objective of increasing S&T activity by training front line staff to treat patients on scene. Hence more

Table 4. Summary of scenario tested & performance measures used in the model. Performance measures in bold were rated as of high importance by the stakeholders.

Scenario	Description	Base Model	Level 1	Level 2	Level 3
Scenario 1	Increase percentage of CAT Hear & Treat intervention	64%	74%	79%	84%
Scenario 2	Increase percentage of See & Treat (incl. referral)	33%	35%	40%	45%
Scenario 3	Increase percentage of Alternative conveyance	25.4%	35%	40%	45%
	Outputs (Performance measures)				
Name	Explanation	Origin			
Red8	Percentage red cases answered within the 8-min target	Based on the pre-2017 national target for responding to Red calls			
Red9	Percentage red cases conveyed within the 19-min target	Based on the pre-2017 national target for conveyance of Red calls			
Green30	Percentage green cases meeting the 30-min target	Based on the pre-2017 regional target for responding to Green calls.			
ED Cases (ED)	Percentage of cases resulting in ED	Stakeholder chosen			
Alternative Cases (Alt)	Percentage cases resulting in conveyance to Alternative care providers	Stakeholder chosen			
S&T Cases (S&T)	The percentage cases result in non-conveyance and clinical referral	Stakeholder chosen, relates to the newly introduced services			
H&T Cases (H&T)	Percentage cases resolved over the phone (no ambulance vehicle dispatched), i.e., resulting in H&T	Stakeholder chosen, relates to the newly introduced services			
Non-conveyance vs Conveyance (NC :C)	Percentage cases result in conveyance to a hospital ED or an alternative health care provider compared to Percentage of cases that result in no conveyance (dealt with on scene or resulted in H&T)	Stakeholder chosen, relates to the aim of reducing conveyance to the ED.			

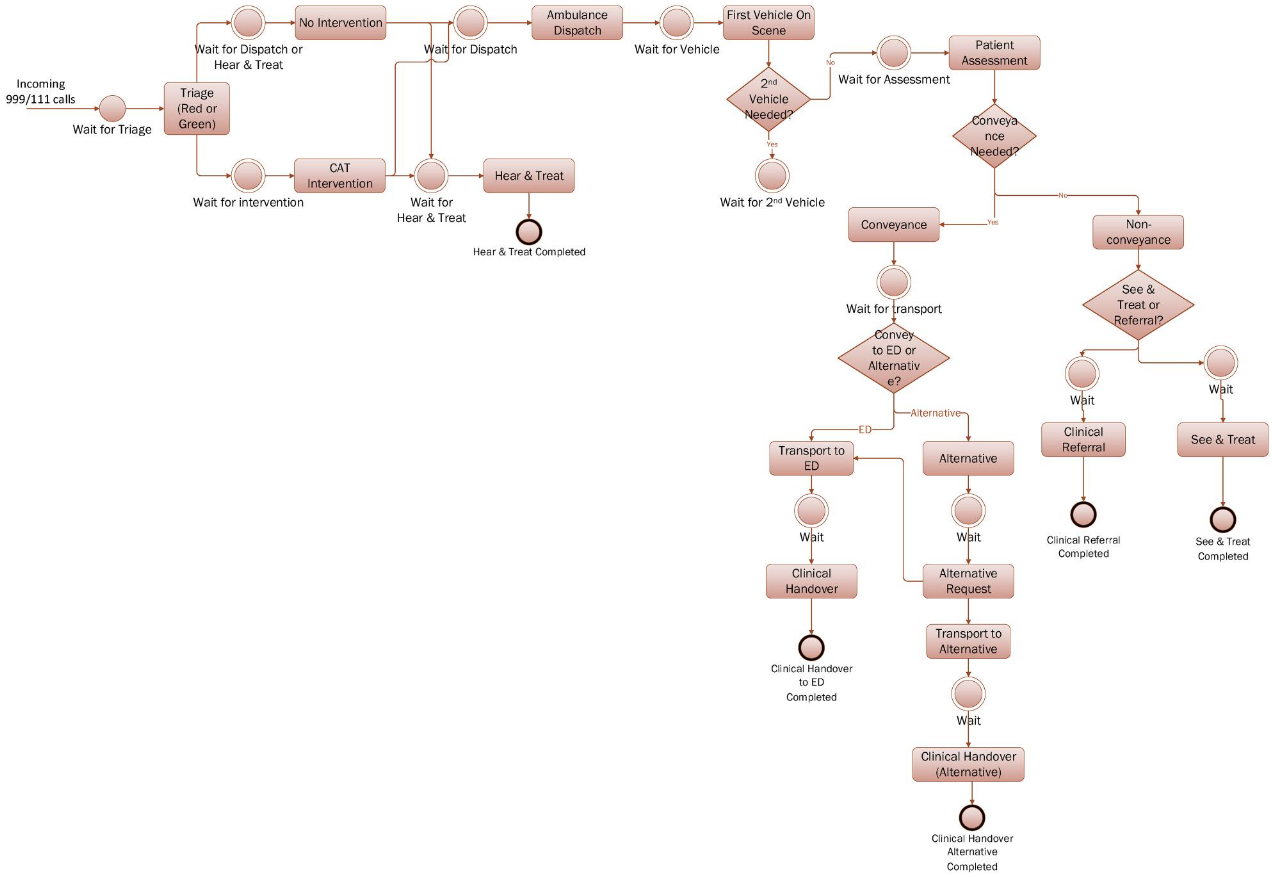

Figure 2. Process flow diagram showing the patient call cycle developed with the stakeholder group for Model 1.

patients are sent to both S&T and clinical referrals, hence introducing an increase to 35%, 40% and 45% from 33%. Scenario 3 is linked to objective 3, which involves improving the accessibility of alternative pathways as a result of improving the clarity of the paramedic pathfinder, increasing it from 25% to 35%, 40% and 50%, respectively.

A process flow diagram using post-it notes was developed with the stakeholder group. The process flow diagram displayed in Figure 2, was tidied up and validated with the stakeholder group and the project champion post-workshop.

4.1.2. Modelling stage 2: Model development

A simulation model was created using a commercial discrete-event simulation (DES) software SIMUL8 (SIMUL8.com). A DES modelling approach is adopted to represent the randomness present in the ambulance call cycle and to allow tracking of individual patient calls as they progress through the ambulance call cycle. This was considered appropriate to ensure that wait times and throughput can be accounted for all patient calls over time and to understand the impact of the new services on the operational performance of the AS. The model was created in a short period of time (2 wk) outside of the workshop environment, based on the process flow diagram developed with the stakeholders in stage 1 (Figure 2). Appendix 1 provides a detailed description of the model logic and simplifications.

The model is based on one week's activity representative for the busiest months (October, November and December) in year 2015 based on the data provided for one specific division in the region. STAT:FIT was used to fit appropriate statistical distributions and to estimate suitable parameters to the available dataset provided from the ambulance service. The distributions and parameters assigned to each activity are detailed in Appendix 2, Table 1. To ensure the model provided statistically accurate results, a warm up period of 8640s (1 day) was set to remove any initialisation bias and 30 replications were performed, using a 5% precision level (Hoad et al., 2011).

Model verification and validation was performed throughout the modelling cycle 1 (Robinson, 2014). The modeller verified the model to ensure that it worked as intended (Sargent, 2013). It was also validated with the project champion to ensure that it was representative. Further validation took place at the third and fourth workshop with the stakeholder group and changes were made according to the feedback provided. Details of the model black-box validation undertaken are provided in Appendix 3.

4.1.3. Modelling stage 3: Experimentation

The experimentation workshop was held approximately 2 weeks after workshop 2. Five stakeholders attended the workshop, including four core members who had attended the previous two workshops and one additional paramedic, who attended for the first time. The aims of the workshop include the following:

- Model demonstration and validation
- Scenario analysis and debating the desirable and feasible solution space.
- Reflections on model results and feedback

The workshop participants found the model representative of their system and accepted the general structure as accurate. Some changes were deemed necessary to rectify lower than expected Red8 and Red19 time targets and hence the logic counting the time for a call to be completed was revisited. In addition, participants pointed out that the ED percentage was too high and so the team revisited the data analysis after the workshop to amend the proportion of patients sent to ED in the model.

The results for each scenario, including the base scenario were shown to the stakeholder group, which also served as a means of further validating the model and its results. Table 5 shows the scenario results produced by the updated model after workshops 3 and 4. The model results were discussed at length with the group.

The group agreed that the system in the Base Scenario worked well. The Red8 and Red19 measures of 72% and 86% do not reach the expected target of 75% and 95% respectively, whilst Green30 with 93% are well within the target of 85%. It is noted that these numbers are a direct result of using the available resources, without taking responsive measures to ensure the 8- or 19-minute targets are achieved, which is what happens in reality. This explains that Red8 and Red19 targets are lower than those in real life. The stakeholders reflected that 40% of cases resulting in ED was high considering the number of alternative pathways available. Conveyance to ED results into longer overall call cycle times, affecting the Red8 and Red19 time-targets not being achieved due to travel and patient handover when arriving to ED. Alternative conveyance has the benefit of taking a lot less travel time as alternative care providers are usually more local to the patients then ED.

Scenario 1 achieves the highest impact on the first three time-based targets, the higher the increase in Hear & Treat patients at the start of the call cycle, the better the targets perform. Conveyance, and in particular ED conveyance, reduces slightly. Scenarios 2 and 3 did not show any improvements on the time-based targets. Scenario 2 results in a slight reduction in conveyance to ED and Alternative with the highest increase in S&T and non-conveyance rates. For Scenario 3 increased use of Alternative pathways results in a decrease of conveyance to ED, whilst Alt increases as anticipated, however it does not perform as well as scenario 1 as all other results remain the same as the Base Scenario.

There was consensus amongst the group that Scenario 1 provided the best outcomes. As expected, it directly affects Hear & Treat patient numbers, one of the most important criteria chosen by the group. It also improves the time-based targets in comparison to the baseline scenario and other scenarios, which meant that the group unanimously chose it as their preferred scenario.

4.1.4. Modelling stage 4: Implementation

The implementation workshop took place one week after workshop 3. This workshop was attended by three of the four stakeholders that had attended the previous workshops. Due to the short project timescales, it was decided to proceed with the workshop, however under normal circumstances, a wider stakeholder attendance with representation from different parts of the organisation and levels of hierarchy would have been preferred. This is to ensure that the implementation plan is considered from different perspectives, but also to include those with decision-making power (Tako & Kotiadis, 2015). The aims of this workshop included the following:

Table 5. Summary of model results by scenario.

Scenario	Level	Red8	Red19	Green30	ED	Alt	S&T	H&T	NC:C
Base Scenario	H&T:64% S&T: 33% Alt: 25.4%	71.4%	85.7%	93.1%	44.6%	**10.8%**	**24.7%**	**19.9%**	**50:50**
Scenario 1:	74% (+10)	73.8%	86.9%	94.8%	38%	**10.4%**	**23.8%**	**27.9%**	**52:48**
	79% (+15)	75.2%	87.5%	95.7%	37.1%	**10.2%**	**23.3%**	**29.4%**	**53:47**
H&T %	84% (+20)	76.2%	88.2%	96.7%	36.4%	**10.0%**	**22.8%**	**30.9%**	**54:46**
Scenario 2:	35%	71.4%	85.7%	93.2%	38.3%	**10.5%**	**26.3%**	**24.9%**	**51:49**
S&T %	40%	71.4%	85.8%	93.2%	35.5%	**9.7%**	**29.8%**	**24.9%**	**55:45**
	45%	71.4%	85.8%	93.2%	32.6%	**8.9%**	**33.5%**	**24.9%**	**58:42**
Scenario 3:	35%	71.4%	85.7%	93.2%	35.4%	**14.9%**	**24.7%**	**24.9%**	**50:50**
Alt. Conveyance %	40%	71.4%	85.7%	93.2%	33.3%	**17.1%**	**24.7%**	**24.9%**	**50:50**
	45%	71.4%	85.7%	93.2%	31.2%	**19.2%**	**24.7%**	**24.9%**	**50:50**

Note: Numbers in bold show performance indicators rated as most important by the stakeholders (percentage alternative, See &Treat and Hear & Treat cases and non-conveyance vs conveyance ratio), shaded cells show best performing indicators.

- summary of model changes and results,
- identify risks and feasibility of changes required to implement model results,
- identify potential barriers to change and
- plan action trail.

After the third workshop, further scenarios had been added to the model, which consisted of combination of the three scenarios. However, the participants were not in favour of these combined scenarios, due to the added risk of introducing more than one change. Whilst they achieved better results overall, the participants felt that the investment required from the trust and staff would not be viable. This was not surprising given the risk adverse attitude of the organisation.

The group undertook a risk and feasibility analysis of the preferred scenario (scenario 1) and concluded that its implementation was achievable. Next, the group explored the necessary resource and process changes required to overcome potential barriers. This discussion provided an opportunity to uncover underlying challenges to implementation. Identified resource changes included increasing CAT staff and desk space, while process changes focused on the scope of practice and autonomy of CAT staff.

Key barriers identified included funding constraints, resistance to change, lack of support for CAT staff and the organisation's risk-averse culture. To facilitate implementation, the group identified follow-up actions and assigned responsibilities. These actions included sharing study findings with CAT staff and the wider organisation, developing a training programme for CAT staff and engaging with the commissioner to secure approval for changes in the terms of service. The cost of legal protection was also discussed. Additionally, it was suggested that the project results and the benefits of increasing CAT Hear & Treat intervention needed to be formally presented to management to gain approval for implementation by the Trust.

A follow-up meeting with the AS Trusts Senior Leadership Team took place where the model results were presented. This marked the conclusion of the first modelling cycle. While the team showed interest in the model findings, they also expressed concerns that an increase in Hear & Treat activity, would mean a reduction in their income. It was agreed that the AS trust would investigate the financial impact of introducing any additional increases to Hear & Treat.

4.2. Modelling cycle 2

After the first modelling cycle, a new Ambulance Response Programme (ARP) was introduced in all Ambulance Services(AS) trusts nationally on 19th July 2017, aimed at improving the underperformance of the ambulance service and patient quality of care. The changes introduced (as outlined in Section 3) concerned primarily the categorisation of calls and response time targets. This would mean that the model developed in the first modelling cycle did not report results that would be considered relevant by the AS Trust, who were also interested to explore how these changes would impact their performance. As a result, it was agreed that a second modelling cycle would be undertaken to adapt the model.

Modelling cycle 2 focused primarily on adapting the model developed in the first cycle, hence an expert mode was deemed suitable as it was considered that the problem and stakeholder requirements had not changed. A brief account of the modelling activities undertaken follows next.

4.2.1. Modelling stage 1: Conceptual modelling

During this stage the focus was on understanding the new APR system and how this can be incorporated in the originally developed model. The modeller read available reports, undertook interviews with ambulance staff and on-site observations to gain a deeper understanding of the ARP and how the call cycle system was affected. This resulted in a slightly modified call cycle to account for the early distinction of Category 1 calls, at a pre-triage activity to forward cases faster to vehicle dispatch (Figure 3). Furthermore, relevant data were collected for the new categories of call types (C1, C2, C3 and C4), and associated activity durations that depend on the type of call such as triage, ambulance dispatch etc. For data not available or not collected by the ambulance service, such as triage and hear and treat duration, on-site observations and expert opinions from interviews with call handlers and the CAT team were used.

The modelling objectives were kept the same to those in the first modelling cycle, noting that in other situations, variations to the objectives can be expected if changes to the stakeholders' needs or the nature of the problem are identified. The response time performance measures to assess achievement of objectives were changed in line with the new response time standards introduced (Table 1). The average time responses for each call category are used instead of old Red8, Red19 and Green 30 targets, and not the 90^{th} centile as they represent more extreme situations.

4.2.2. Modelling stage 2: Model development

The adapted simulation model is very similar in structure to the original model. The main difference is that it now tracks four types of calls (C1, C2, C2, C4) which have different activity time durations. New data were collected and the model updated.

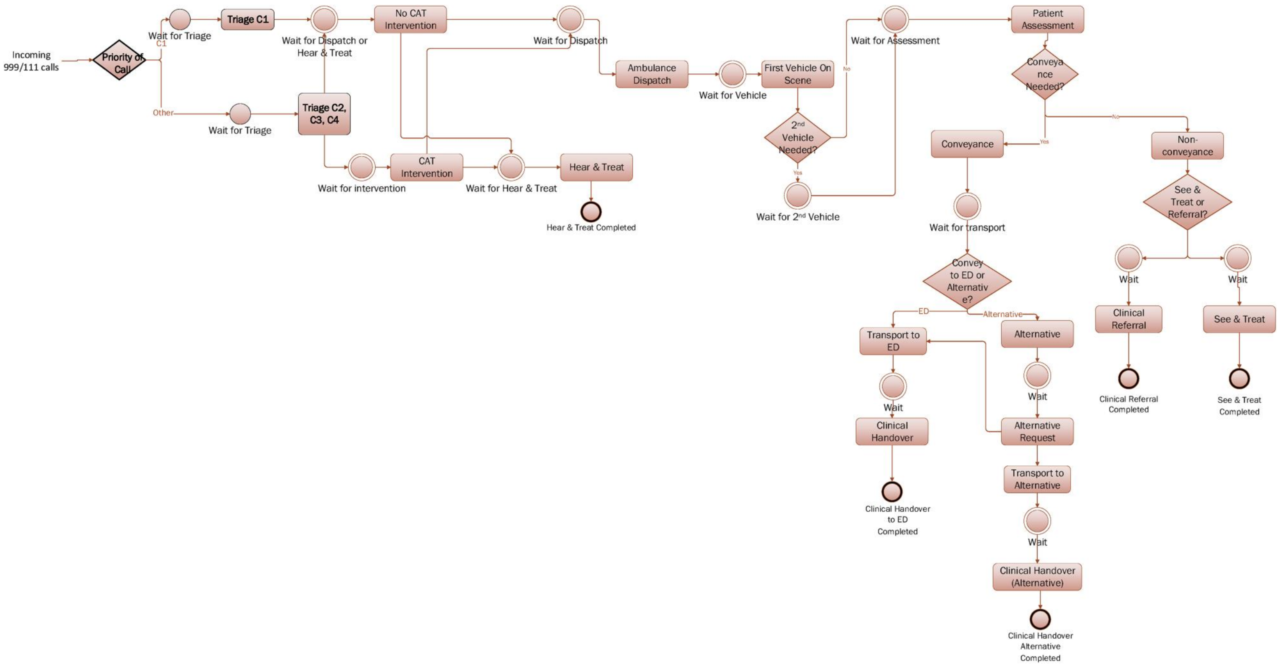

Figure 3. Process flow diagram of the new patient call cycle amended for Model 2. Changed components are shown in bold letters (Priority Call, Triage C1 and Triage C2, C3, C4). The rest of the pathway is similar to that of Model 1.

Table 6. Validation of Model 2 results against nationally published AS data in October 2023 (Source: 20231109-Stats-Note-AQI.pdf (england.nhs.uk).

	C1 (Standard: Avg 7, 90th 15min)	C2 (Standard: Avg 18, 90th 40min)	C3 (Standard: 90th 120min)	C4 (Standard: 90th 180min)
Model results	Avg: 00:08:54 90th: 00:18:08	Avg: 00:36:21 90th: 01:30:44 (90 min)	Avg: 2:21:04 (141 min) 90th: 5:32:03 (332 min)	Avg: 2:34:01 (154 min) 90th: 06:05:14 (365 min)
AS published data (Oct 2023)	Avg: 00:08:40 90th: 00:15:28	Avg: 00:41:40 90th: 1:30:02 (90 min)	Avg: 2:31:05 (150 min) 90th: 6:06:46 (366 min)	Avg: 2:50:10 (170 min) 90th: 6:55:40 (410 min)

The different time durations of activities, such as C2,3,4, Triage and CAT intervention was set using visual logic code, which is called upon depending on the type of call going through each time. The model also features a separate "pre-triage" activity which filters C1 calls from other call types early on in the call cycle to enable a fast response (Figure 3). Triage for the other call categories (C2, C3 and C4) takes now longer to ensure call handlers have enough time to assess the patient status and to make appropriate decisions.

The second model was validated with the project champion and the results compared against nationally published Ambulance quality indicators using as proxy data for one busy month (October 2023) (NHS England, 2023). From the comparisons (Table 6) the model seems to behave reasonably well compared to nationally published data. The average C1 and C2 respectively are above the standard for both model and real life, the real life 90^{th} Centile for C1 is close to the standard (15.5 min), while it is slightly higher (18 min) in the model. Both real life data and model results are above standard for C2, C3 and C4, whilst model 90^{th} centiles are by few minutes lower than real life data, which indicates that the model is a reasonably accurate representation of the real life ambulance service.

4.2.3. Modelling stage 3: Experimentation

The same future scenarios as Model 1 were tested to understand the impact of introducing further Hear & Treat, See & Treat and Alternative Conveyance in the call cycle.

The scenario results for model 2 are presented in Table 7. As it can be seen, the average values for C1, C2, C3 and C4 calls indicate that response times exceed the new standards. For example, Category 1 (C1) calls do not achieve the 7-min target, instead averaging in the higher end of 8 min. Similarly, for Category 2 (C2) calls, the base scenario shows an average response time of 36.5 min, exceeding the expected 18-minute average, while the 90th percentile is expected to be around 40 min.

With the introduction of Hear & Treat (Scenario 1) some reduction on average response times for each call category can be observed, however average response times for C1 calls remain the same across all scenarios, the highest decrease is noted for C4 calls, those classified as less urgent. This is expected as C1 calls for life-threatening conditions are

Table 7. Alternative scenarios for model 2, showing average model results for 9 performance measures. Numbers in bold show performance indicators rated as most important by the stakeholders (percentage alternative, See &Treat and Hear & Treat cases and Non-Conveyance vs Conveyance ratio) in modelling cycle 1, shaded cells show best performing indicators.

Scenario	Level	C1	C2	C3	C4	ED	Alt	S&T	H&T	NC:C
Base Scenario	H&T:64% S&T: 33% Alt: 25.4%	8.9	36.35	141.0	154.0	46.10%	**9.90%**	**29.00%**	**14.00%**	**44:56**
Scenario 1:	74% (+10)	8.9	30.45	124.1	130.8	44.70%	**9.50%**	**29.00%**	**17.00%**	**46:54**
H&T %	79% (+15)	8.9	28.20	103.7	118.9	41.60%	**9.40%**	**29.00%**	**19.50%**	**49:51**
	84% (+20)	8.9	27.41	98.3	115.0	38.50%	**9.50%**	**29.00%**	**23.00%**	**52:48**
Scenario 2:	35%	8.9	36.35	145	154.5	43.00%	**9.70%**	**31.40%**	**15.00%**	**59:41**
	40%	8.9	36.35	145	155.0	41.50%	**8.90%**	**34.50%**	**15.50%**	**50:50**
S&T %	45%	8.9	36.35	146	155.6	40.40%	**8.20%**	**36.50%**	**15.00%**	**52:48**
Scenario 3:	35%	8.9	36.35	144.2	154.5	41.00%	**16.00%**	**29.00%**	**14.00%**	**43:57**
	40%	9.0	36.35	145.4	155.0	38.00%	**19.00%**	**29.00%**	**14.00%**	**43:57**
Alt. Conveyance %	45%	9.0	36.35	146.6	156.4	36.60%	**21.00%**	**29.00%**	**14.00%**	**43:57**

streamed first and very few are sent for Hear & Treat, See & Treat or Alternative conveyance. However the other scenarios do not seem to make a significant difference on C2, C3, C4 average response times. As a result, it is noted that there is little further improvement to be gained in response times as the new call classification (Turner et al., 2017) helps to identify appropriate response early on and so urgent calls are prioritised. A bigger impact is seen on non-conveyance rates, S&T and H&T. Scenario 1 achieves a higher proportion of H&T cases and also a higher non-conveyance rate. Scenario 2 has a direct impact on the number of See & Treat cases, resulting also in an increased non-conveyance rate. All scenarios influence a reduction in conveyance to ED, with a more significant reduction achieved by Scenario 3. The non-conveyance vs conveyance ratio remains the same to that of the base scenario. This scenario considers reduction of ED conveyance, which is compensated by the increase in conveyance to alternative pathways, as a result non-conveyance rates do not change.

4.2.4. Modelling stage 4: Implementation

The findings from the scenarios tested were shared with the stakeholders. These consolidate the findings from the first modelling cycle. Again scenario 1, which was the preferred scenario by stakeholder group, performs slightly better. It was however highlighted that a combination of all scenarios would achieve the highest improvements. This marked the end of the second modelling cycle and the study.

5. Discussion

This paper presents a case study of a simulation study that evaluates the impact of introducing changes to patient flows on the efficiency of a UK ambulance service. Due to changes introduced to the reporting of ambulance response time targets, the results of the modelling study became soon obsolete, hence a second modelling cycle was needed to adjust the model and its findings. This study contributes to our understanding of the ambulance call cycle and impact of introducing alternative services (hear & treat, see & treat and conveyance to alternative care facilities) on the performance of the ambulance service and its ability to reduce conveyance of patients to the emergency department. Furthermore, it contributes to the model development process (life-cycle) literature, by proposing a methodological framework that prescribes how insights gained from a previously developed simulation model can be consolidated through a second modelling cycle.

The discussion is organised as follows. We first reflect on the implications of the study findings for ambulance services (5.1). Secondly, we compare the differences between the first and second modelling cycles, reflecting on the role of the modeller, stakeholders, facilitation requirements in the modelling process (5.2), followed by the benefits of adopting a combined facilitated-expert mode approach in two modelling cycles (5.3). Next, we compare and reflect on the differences to other model development frameworks (5.4), followed by the limitations of the study and directions for future research (5.5).

5.1. Significance of the results for the ambulance service

The findings of this study provide useful insights that add to our knowledge base about how simulation modelling can support improvements in the operational performance of ambulance services. The model provided a better understanding of the ambulance service call cycle and the efficiencies that can be gained. The scenarios tested provided evidence that the introduction of the new services has a positive impact on the AS performance and that the highest impact is achieved by increasing the activity of CAT hear & treat (scenario 1). This achieves improved quality of care as it leads to faster response times and because care is given early on in the call cycle when needed without incurring ambulance dispatch. This outcome was unanimously accepted by the stakeholder team at the workshops in the first modelling cycle. They also noted the benefits of reduced ED attendance and higher non-conveyance rates, two performance indicators considered important. The same conclusions were drawn in both modelling cycles.

The findings of this study are beneficial to healthcare professionals to help identify the points where the ambulance service can achieve efficiencies, leading in turn to less ambulance conveyances, especially conveyance to ED, and so contributing towards reducing the burden on EDs and the wider emergency system. The model results confirmed to the AS stakeholder team that the addition of ambulance-based and community-based services, if integrated efficiently within the call cycle, can improve performance, of which the CAT hear & treat service can achieve more significant improvements. It is noted that these additional services were rolled out on a pilot basis in the regional AS trust at the time of this study and subsequently the year after to all other ambulance services nationally as foreseen by the first review in 2013 (Keogh, 2013). While we cannot claim that the changes made were an outcome of this study, a direct benefit of this study was that it helped the stakeholder team realise the benefits and impact of these changes on their service.

To this date, the regional ambulance service continues to make use of the clinical assessment team (CAT) to provide hear and treat services to patients. The Trust's quality improvement plan in 2016 (after the completion of modelling cycle 1) outlined the increase in the size of its Clinical Assessment Team with the view to improving call response times and to ensure the welfare and triaging of patients waiting for an ambulance response. A similar action was undertaken in the two subsequent years 2017–18, after the completion of the modelling cycle 2. After the pandemic (2021 onwards), the AS trust has further enhanced the service with more qualified resource such as GPs who can handle more complex cases.

5.2. Comparison of the first and second modelling cycle

The two-cycle modelling framework reported in this study adopts two different modelling practices. The first modelling cycle adopted a facilitated approach, which defined the problem frame and model boundary of the study, whilst the second cycle adopted a primarily expert mode, focusing on adapting the original simulation model to represent the changes to the calculation of ambulance response times. Table 8 shows the main differences in the roles the stakeholders and modelling team undertook in each stage of the two modelling cycles. While the modelling objectives were similar in both cycles, the focus of the activities undertaken were different. In the first cycle, both the modelling and stakeholder team co-created a common problem definition and model objectives, culminating with the development of a simulation model that both teams considered relevant. This required a facilitated approach and the PartiSim modelling framework and tools (Kotiadis et al., 2014; Kotiadis & Tako, 2018; Tako & Kotiadis, 2015) were adopted to guide the modelling process. The modelling team spent significant effort to design, plan and facilitate the four facilitated modelling workshops and to engage with the stakeholder team, besides developing the simulation model.

The second modelling cycle primarily focused on adapting the model to reflect the changes to the measurement of ambulance response time targets. This changed the nature of interactions with the stakeholder team. While stakeholders were still engaged in the study the information required was collected primarily on a one-to-one basis, through interviews, questionnaire surveys and observations, instead of workshops. This was deemed appropriate to ensure stakeholders' time is used efficiently.

5.3. Benefits of adopting a combined facilitated-expert mode study in two cycles

Literature on behavioural operational research (OR) (Kunc et al., 2020) and broader OR practice refer to the socially situated nature of OR interventions (Ackoff, 1977; Keys, 1997; Shaw et al., 2003; White, 2006; White, 2016; White et al., 2016). Implementing a study with real world stakeholders, allowed the modelling and facilitation processes to embed service-specific knowledge and stakeholder concerns, thereby ensuring relevance and practical outcomes.

The first modelling cycle aimed to support the service in understanding the impact of introducing alternative services in the ambulance call cycle. It helped the stakeholder team realise that the highest benefits could be gained from utilising the clinical assessment team. Prior to our workshops the stakeholder team was not clear of these benefits.

The second modelling cycle, was undertaken in response to new changes introduced to ambulance services nationally in how ambulance calls were classified and response times measured, as well as the AS desire to confirm the initial model findings. Even though facilitated modelling was undertaken in the first modelling cycle only, it enabled a more transparent and pragmatic OR process to be undertaken throughout the study (White, 2016). The modelling team gained a better understanding

Table 8. Comparison of the roles of stakeholders and modeller in the first and second modelling cycle.

	Modelling Cycle 1		Modelling Cycle 2	
	Stakeholders	Modeller	Stakeholders	Modeller
Conceptual modelling	Engage in workshops with the modeller(s) to define the model objectives, define the system and its boundaries, scope the model contents and relationships between them,	Engages in data collection, onsite observations to get an initial understanding of the problem. Engages with stakeholders to facilitate conceptual model development in workshops, using SSM tools and facilitated discussion.	Provide 1-to-1 input through interviews and questionnaire surveys. Conceptual model validation.	Interviews, observations to revise the conceptual model developed in cycle 1, revise objectives, system boundaries, and design the scope of the new model.
Model development	Not directly involved, primarily input from project champion to validate the model. Support with data collection.	The conceptual model is converted into a simulation model.	1-to-1 input through interviews and questionnaire surveys for data collection. Model validation with project champion.	Makes changes to the existing model to capture the revised conceptual model. As there is already a model, the changes focus on the addition or amendment of parts that have changed in the model. Collates historical and contextual data from stakeholders to include into the model.
Experimentation	Understand and validate the model and identify changes (scenarios) that can be tested and learning that can be achieved.	Engage with stakeholders to identify scenarios that can improve performance and device experiments. Supports stakeholders to understand impact of changes on system behaviour.	Provide 1-to-1 input through interviews and questionnaire surveys. Scenario validation primarily by project champion.	Re-run the original scenarios in the adapted model and identify if any additional scenarios should be added. Identifies insights from experimental findings and seeks 1-to-1 input from key stakeholders/project champion to validate the findings.
Implementation	Work with the modeller(s) to identify and agree feasible action to be taken based on findings.	Present findings and scenario results. Proposes actions to achieve the improvements identified.	Seek to understand findings and consolidate the learning achieved from cycle 1.	Develops a report to feed back to stakeholders the updated findings and proposes recommendations.

of the social, cultural, and environmental forces at play that shape up the real life setting, while the stakeholder team gained confidence in the model and its findings particularly as their perspectives were reflected in the scenarios tested and system representation (Wankhade et al., 2018; White, 2016). This in turn ensures model validity and development of context-situated models.

The combination of two modes of practice adopted, a facilitated mode in the first cycle and an expert mode in the second, helped consolidate the insights gained and confirmed the model's utility. The model results were received with great enthusiasm by the stakeholder team at the end of the first cycle (workshops 3 and 4) and when the report was shared with them in the second cycle. They were very keen for the findings and the action plan developed to be implemented (Harper et al., 2021).

As models developed in facilitated studies reflect the realities of service delivery, their use can be further extended. The structured facilitated modelling process ensures transparency, stakeholder buy-in, and contextual relevance. For example, the model findings can help to draw insights that could be relevant to other regional healthcare settings. Alternatively the models themselves can be rapidly adapted or reused for different regional settings in an expert mode, maintaining their core structure while accommodating regional variations. From a practical perspective to enable model re-use, a concerted effort to increase sharing and accessibility of healthcare models is needed. This can help broader implementation without the need for repeated full-scale facilitation and stakeholder workshops.

While participative modelling is essential in healthcare to ensure real-world relevance, a combined approach, starting with a facilitated cycle that is followed by an expert mode cycle, can be effective for extending the use of model-based solutions. By reducing the need for extensive stakeholder engagement in subsequent modelling cycles, models can be implemented more efficiently across multiple ambulance services or other health settings. This can help to ensure consistency while embedding operational differences at local level. It furthermore has the potential to strengthen the practical value and generalisability of healthcare modelling, contributing to a more meaningful transfer of learning and implementation (Gogi et al., 2016; Monks et al., 2016).

5.4. Comparison with existing facilitated modelling frameworks

The methodological framework proposed in this paper differs from other modelling frameworks in the literature. Notably, the PartiSim (Tako & Kotiadis, 2015) approach was adopted in the first modelling cycle to actively engage the stakeholders in the modelling process. In contrast, the second cycle adopted an expert mode, with the key distinction that both the modelling team and stakeholders had already developed a high level understanding of the system and there was agreement about the modelling objectives. The framework presented here is closer to that developed by Jones et al. (2022) in that it aims to further consolidate the learning achieved from the model and its outcomes and to inform the ongoing improvement initiatives in the real system.

The study by Jones et al. (2022) adopts two modelling cycles, each involving a single facilitated workshop, while the modelling itself was undertaken as a back office activity. Their second cycle extended the original model and scenarios based on input from a different group of stakeholders who identified additional factors for consideration. In comparison, our framework involves a fully facilitated approach in the first modelling cycle incorporating four workshops that supported the model development process (conceptual modelling, experimentation and implementation). The second cycle primarily adapted the original model to incorporate the changes introduced nationally in 2017 to the calculation of ambulance response times. While some stakeholder engagement was maintained, it took a different form. Instead of additional workshops, the modelling team held one-to-one interviews and questionnaire surveys, to collect further knowledge and data as required for the second model.

The fully facilitated approach in the first modelling cycle established a clear understanding of the system boundaries, model objectives and expected outcomes, which meant that additional workshops were not needed. The second model was developed to primarily confirm the findings of the first model. The findings were fed back to the stakeholders in a written report. If the results of the second model differed from the first model, another workshop as suggested by Jones et al. (2022) would have been warranted.

Similar to Jones et al. (2022), we observed that the facilitated approach fostered stakeholder buy-in and confidence in the model findings (Jahangirian et al., 2015). However, like previous studies, we encountered challenges with ensuring implementation of the findings and follow-on actions (Brailsford & Vissers, 2011; Fone et al., 2003; Jones et al., 2022; Young et al., 2009). A key challenge in this study was the nationwide changes introduced to ambulance services in 2017, following a system-wide review (Turner & Jacques, 2018). This represents a common challenge in healthcare modelling, where external policy changes, beyond the control of individual services or the analyst team, can affect model relevance (Braithwaite, 2018).

We responded to these changes with a second modelling cycle, to further support the stakeholder team with their decision making. Given the stakeholder team had validated the model and its results in the first cycle, we focused on making only necessary changes to the model, while keeping the scenarios tested the same.

Tako and Kotiadis (2015) and also Jones et al. (2022) acknowledge the demanding nature and requirements for engaging with stakeholders in workshops and hence suggest that modellers consider whether a facilitated approach is feasible or indeed needed. And so, the extent of stakeholder involvement can differ. For example Jones et al. (2022) held only one workshop with stakeholders. The Simtegr8 approach (Tako et al., 2019) includes two facilitated workshops with a further workshop with service users (patients). This study did not hold any workshops in the second modelling cycle, whilst adopting a fully blown facilitated approach in the first modelling cycle.

5.5. Limitations and further work

Of course it is important to consider the limitations that could have affected the current study. First, it would be useful to consider the implications of adopting a two-cycle approach. It is noted that the two modelling cycles had different aims, the facilitated mode of cycle 1 is focused on model implementation and usefulness which can help ensure that action is taken by the service. In the second cycle, which adopted an expert mode, the results were delivered as a report, which meant that there was limited opportunity for interaction and learning with the stakeholder team. In our case the model results were not different to the findings of the first model. In addition, due to limited staff resources, another workshop was not set out in our study design. However, should there have been additional or different findings, a facilitated workshop with the stakeholder group would have been beneficial. One disadvantage of an expert mode approach is that it was not possible for the modelling team to establish how the second model could have impacted the stakeholders' perceptions of model and usefulness of the results. Whilst we received positive feedback from the project champion, this approach did not provide us an opportunity to support further consolidation of the stakeholder learning in the same way that would have been possible with a facilitated approach. In our case the consolidation of findings was impacted primarily by the stakeholders' high level of engagement with the study established in the first cycle. Responsibility for advancing the outcomes and implementing the proposed actions would rest with the stakeholder team.

Additionally, considering the participant group involved in the study the following observations can be made. The participant group of the first cycle was not as multidisciplinary as other PartiSim studies, for reasons out of our control. There was full consensus at the workshops and unanimous agreement with the actions to be taken. No obvious conflict or disagreement arose in the workshops, which is different to the author's experience of other participative projects (Kotiadis & Tako, 2018; Tako et al., 2019; Tako & Kotiadis, 2015). It is recommended that some diversity amongst participants is achieved, if possible. If other roles or staff of the ambulance service were involved, the outcomes of the study could have been different. Group composition can impact the diversity of opinions expressed, and the group were happy that the study achieved the objectives defined at the outset. Future studies could explore the impact of group composition against project aims to identify typologies of stakeholder involvement.

Hämäläinen and Lahtinen (2016) suggest that strategic behaviour can affect the outcome of group processes in participative modelling projects, allowing stakeholders to influence the outcome by intentionally emphasising specific features of the problem. It was observed that the group of participants chose Scenario 1 as the most feasible scenario, as opposed to the combined scenarios which had the potential to deliver optimum results. Their opinion was based on the organisations risk averse attitude with implementing high-risk changes. Interestingly, their opinion differed to that of the project champion. Had the project champion attended the workshops, they might have influenced the selection and agreement on the preferred scenario.

Moreover, the model developed in this study is a simplification of the real AS call cycle, which in real life is more complex. Simplifications were necessary to enable rapid model development in a short project timescale and to ensure that the discussion at the facilitated workshops (cycle 1) focused on the main model objectives. The models were however validated with the stakeholder team and the project champion (cycle 1) and only with the project champion (cycle 2) which ensured that the models were relevant. One limitation of the first model is that it aggregates the 4 green patient categories (green1, green2, green3 and green4) into one green category and it assumes that the target waiting times for all these patients is 30 min. This was considered suitable and agreed upon with the stakeholder team, as all green patients follow a similar pathway in the models, and so it would not affect the results. This simplification was introduced as the stakeholder team was more concerned with understanding how the changes introduced would impact the waiting times for urgent patient (red) categories that require a more immediate response. However, if a more detailed view of the impact of the increase in the proportion of Hear & Treat, See & Treat, and CAT intervention activities on efficiencies achieved for each individual category of patients was required, this simplification would have not been suitable. This was rectified in the second model developed with the four new and simpler patient classifications introduced.

In addition, the models developed use data for one division of the regional ambulance service. It is expected that a similar behaviour would be displayed in other equivalent systems. Due to time limitations, it was not possible to test our results against other divisions or regional ambulance services. In addition, some data was not possible to obtain as it was not collected by the ambulance service or not available to the modelling team, which meant that we relied on expert judgements shared with us based on the stakeholders' experiences, either through the workshops (first cycle) and our one-to-one questionnaire surveys and interviews (second cycle). More real life data could have produced more accurate models and results.

Further research is also needed to provide more evidence about the benefits gained through the use of a facilitated approach in simulation studies. Future work could consider the role of adopting a facilitated approach by comparing the difference in the perceptions and cognitive processes between stakeholders involved in the modelling process versus those not involved.

6. Conclusions

This paper presents a case study that uses simulation to evaluate the impact of changes to ambulance services on the operational efficiency of a regional Ambulance Service Trust . The client organisation gained valuable insights about the impact of planned service changes on patient flows and identified opportunities to improve efficiency, particularly by reducing avoidable conveyances to the emergency department. The findings of this study are transferable to other regional ambulance services and the models can be further adjusted and scaled for use in other settings.

A two-cycle approach is adopted, where a simulation model is developed in a facilitated mode in a first cycle and subsequently adapted in an expert mode cycle. This approach can be beneficial. First, it can help secure stakeholder buy-in at the outset of the study by adopting a facilitated approach as it ensures that the modelling objectives, model boundaries and scenarios tested are agreeable and accepted by the stakeholder group. Second, it is useful for extending the model lifetime as it allows the modellers to either modify the model to reflect new system realities in the case of unexpected changes or to further adapt and extend the model to other similar settings. The modelling framework proposed in the current study is applicable to situations, where changes to the real life situation do not require re-negotiation of the modelling objectives and scenarios tested with the stakeholder group. This mode of practice reduces the need for additional workshops, minimising effort for both the stakeholder group and the modelling team. It is claimed that extending the model lifetime can help to ensure transfer of learning and implementation of models, an issue of importance especially to healthcare modelling.

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Ethics

The Research has been logged with the School of Business and Economics and approved June 2016. All participants have consented for their involvement in this research. The organisation and participants are kept anonymous for confidentiality purposes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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