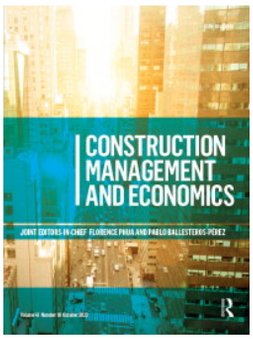

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The role of lean information flows in disaster construction projects: exploring the UK's Covid surge hospital projects

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ABSTRACT

A substantive body of work in project studies argues that an "information flow" lens is very useful in exploring the project management of construction. This paper posits that this is even more applicable to disaster construction projects and, furthermore, lean information flow may play a role in swiftly delivering the disaster construction project. The paper uses the qualitative empirics of the delivery of the UK's Covid surge hospital projects to demonstrate that lean information flows were employed in these projects and assisted in enabling delivery at speed. The paper also describes the autopoietic governance conditions that are necessary for lean information flows to flourish in disaster construction projects and the role that trust may play in these conditions. It warns against some of the drawbacks in enabling lean communication through autopoietic governance.

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Lean information flow; lean communication; disaster construction projects; disaster response

Introduction

Research context and the research question

The twenty-first century has seen an unprecedented growth in disasters and the need to mitigate against them. The severe implications of climate change and the current global pandemic have exacerbated this situation. The need to mitigate these disasters has generated considerable interest in mitigation strategies and the role of disaster construction projects is pre-eminent amongst these. Due to the particularity of the nature of disaster construction projects (in terms of their purpose, objective, environment, and need for extreme responsiveness) compared to traditional construction project organizing, researchers need to identify the specific interventions to support the successful delivery of this type of project. Disaster construction projects aim to immediately deliver the shelter, temporary facility, or other structure to react or mitigate the disruption caused by the disaster (Alexander 2002, 2004, Davidson *et al.* 2007, Hidayat and Egbu 2010, Prieto and Whitaker 2011).

Research shows that due to the features of disaster, information flow plays a critical role in disaster management (Wolbers and Boersma 2018). The information flow process needs to be speedy, succinct, efficient and accurate to support the project's delivery. However, the role of information flow in disaster construction projects remains largely unexplored. A theoretical stance that might be usefully employed in improving information flows in disaster construction projects is that of "lean information flow".

The concept of lean, which was initially utilized in manufacturing operations, aims to identify and eliminate all non-value-added elements from an activity to build a value stream for its effective delivery (Hines *et al.* 2004). This concept has now also been applied to the general construction sector to eliminate unnecessary elements in the project delivery process to improve efficiency (Green 1999). Applying lean information flow is a relatively new area of research endeavour, which derived from lean information management (Hicks 2007, Hölttä *et al.* 2010). Lean information flow aims to eliminate and avoid communication waste to ensure the flow is efficient (Redeker *et al.* 2019). We posit that applying lean information flow in disaster project management may provide a useful lens through which to consider and improve disaster project delivery. Our research question,

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therefore, is as follows: "What role does lean information flow have in the effective delivery of disaster construction projects?"

Structure of the paper

We begin the paper by theorizing lean information flows in disaster construction projects by reviewing the current literature applicable to this investigation. Our activity includes our operationalization of key constructs, disaster construction projects and lean information flows, and we present these in the form of "framework" tables. We continue by describing how we answered our research question empirically using a qualitative interview survey approach in the context of the UK's development of Covid hospitals. We analysed these interviews using template analysis which employs an a priori template of constructs created from our frameworks. We present our findings using our templates that delineate lean information flow in terms of waste elimination. We discuss our findings in the context of our overall research question and use the emergence of the phenomenon underpinning lean information flow to provide speculative propositions of conditions for lean information flow in disaster construction projects. We conclude by considering how far we have achieved our research aim, what theoretical and practical outputs we have created and delineating what further research in this area would be useful.

Theorizing lean information flows in disaster construction projects: a review of literature

Information flow in construction projects

Based on Galbraith's work, all organizations can essentially be regarded as information processing systems (Galbraith 1974). By summarizing the project coordination work in Boeing, Galbraith placed information flow at the core of his approach to organization theory. His study indicates that information flow underpins the project's organizational processes. Tzortzopoulos and Formoso (1999) state that the unavailable and insufficient information normally induces unbalanced resource allocation and irrational decision-making. Pool information flow always delays the project and incurs other project management issues (Tilley 2005, Cheung *et al.* 2013).The foundational role for information flow is also echoed in the work of Winch who proposes that the crucial issue directly influences project decision-making is the lack of information (Winch 2015, Winch *et al.* 2021). We therefore posit that information flow is the heart of project organizing and that it directly relates to project delivery.

Construction projects, which are complex, highly variable, and lengthy, require multiple discipline teams to collaborate for their project delivery (Laufer *et al.* 1994). Due to the plethora of stakeholders (e.g. architectural design team, construction team, engineering team, professional services, client team), information flow, which operates to integrate and exchange among different organizations, directly influences the effectiveness of construction project management (Tan *et al.* 2018). Without timely, concise and precise information flows, project actors cannot conduct rational decision-making to advance the project progress (Dave *et al.* 2014). An investigation indicates that a considerable amount of poor-quality information is generated and transmitted in the construction context (Lofgren and Rebolj 2007), which attracted researchers to focus on the topic such as BIM (building information modelling) and information integration in construction projects. Given the particular context of construction, we propose that information flow plays a critical role in construction project delivery.

The disaster construction project

"Disaster" describes an unpredictable and urgent incident that significantly interrupts daily routine, is inimical to the society's or organization's main values, and challenges managers' decision-making capacity (Homer-Dixon *et al.* 2015, Bundy *et al.* 2016, Williams *et al.* 2017). The disaster can interfere with and have an impact on a variety of social systems ranging from the individual to teams to organizations to whole societies (Unterhitzenberger *et al.* 2021). Williams *et al.* (2017) also state three essential elements of disaster (high-level imperilling on the organization's values, limited time for responding, and unpredicted occurrence and results). Besides, the disaster's environment is mercurial. Even when the disaster has become apparent, its subsequent impact cannot be ameliorated, which may induce further unexpected results. Aiming to increase the efficiency of disaster management, researchers and practitioners have applied project management to manage disaster response to increase the efficiency of disaster management (Moe and Pathranarakul 2006, Crawford *et al.* 2013, Prasad *et al.* 2019).

We therefore regard a disaster construction project as a construction project that is initiated in response to such an unexpected disruption to one or multiple

Table 1. Characteristics of a disaster construction project.

Disaster construction project characteristic	Explanation	Reference
Purpose	The project's aim is to deliver the shelter or other structure to react or mitigate the disruption caused by an emergency	(Moe and Pathranarakul 2006)
Pace	The speed of project delivery is critical	(Kalkman and de Waard 2017)
Operation	The project operates during the emergency cycle (emergency phase and post-emergency phase)	(Kalkman and de Waard 2017)
Resource	The project has limited resource	(Wearne 2006, Chang *et al.* 2011)
Multiplicity of stakeholders	The project has a wide range of stakeholders	(Lagadec 2002)
Multi-role participants	The participants of the project are highly multi-disciplinary	(McLennan *et al.* 2006, Opdyke *et al.* 2017)
Information about the project environment	The project environmental information is intensely uncertain, ambiguous, and limited	(Waugh and Streib 2006)
Impact	Project failure has a severe impact on a variety of social systems	(Kalkman and de Waard 2017)

social systems. Given the disaster in which they are delivered, we posit that disaster construction projects managed during the disaster phase have analogous features to the disaster (i.e. riskiness, opacity of scope, complexity, variability, and ambiguity). We argue that the disaster context makes the project more complex, variable, and preoccupied with speedy delivery. As the disaster typically represents a decisive or even existential threat to a social system (Holton 1987), disaster construction projects need to be specifically undertaken at pace. The disaster project delivery time will influence the speed that the damage of the disaster can be alleviated (Kalkman and de Waard 2017). This means that delays in the disaster project will extend the influence duration of the disaster, which has the potential to damage individuals, organizations or societies. It can be argued that the timely response to and recovery from the disaster situation is the primary objective of a disaster project. Disaster construction projects normally have a considerable number of stakeholders due to the high degree of complexity of the disaster (Lagadec 2002, Opdyke *et al.* 2017). The disaster environment's complexity additionally requires multiple teams from different disciplines to collaborate for delivery (McLaren and Loosemore 2019). Given the variability and ambiguity in the disaster environment, teams regularly cannot get sufficient, reliable, and clear project environmental information (Crichton *et al.* 2005) with implications for the ongoing project decision-making processes (Waugh and Streib 2006). Disaster project management is a disparate field, but we posit that it has, at its core, a distinct range of differentiating characteristics for disaster construction projects. Furthermore, disaster construction projects have two purposes: response and recovery (Alexander 2002, 2004, Davidson *et al.* 2007, Hidayat and Egbu 2010, Prieto and Whitaker 2011). The response project aims to rescue human lives and immediately provide victims with basic subsistence needs. It delivers the shelter, temporary facility, or other structure to react or mitigate the disruption caused by an emergency at once. Regarding the recovery project, it normally initials after the response project and aims to restore damaged or service or to rehabilitate facilities that were struck in disaster. For example, the hospital project in Missouri was built within one year to substitute the original facility that was damaged by an F5 tornado (Peltokorpi *et al.* 2018). However, we intend to research the disaster construction project that aims for the response, as the response project shows a more intense pressure on time and information flow compared to the recovery project and limited research pays attention to such the project environment. We therefore propose the defining characteristics of a disaster construction project namely purpose, pace, operation, multiplicity of stakeholders, multi-role participants, information about the project environment and impact. Further explanations of each of these and the literature from which they are derived is given in Table 1. This paper uses these characteristics in order to explore information flow in disaster construction projects and how this flow impacts on project delivery.

The role of information flows in disaster construction projects

In many contexts, managing information flows is symbiotic with managing disaster. The speedy decisions required in disaster situations need valid information to be effective. In response to this need, information flows need to be effective in delivering this information. This imperative has been recognized in seminal disaster management literature. For example, Egelhoff and Sen (1992) state, "disaster management can be regarded as an information-processing situation and organisations must cope with disaster as information-processing systems". Hagar (2012) echoes this viewpoint emphasizing the direct role that information plays in managing disasters: "disasters precipitate an

increase in communications and present complex information environments. The management of information before, during and after a disaster can have a direct impact on how the disaster is managed".

The centrality of information and information flows, however, is not confined to the response to disaster. A substantive, if not large, the core of project organizing literature places information, and its closely related construct, knowledge, at the heart of supporting project performance. As far back as the 1980s this topic attracted the attention of project researchers (Bishop and Gembey 1985). More recently, Jepsen (2013) explored the information flow in new product development projects (NPD) and found that whilst the project manager plays a central role, they need to be supported by other internal and external core project actors to ensure appropriate and timely sharing of information. It had a particular focus on the role of different project actors in different project phases, however the nature of disaster projects and especially their pace suggests that phases will be overlapping, schedules will be compressed, and an approach based on improving the project delivery efficiency will be chosen (Winch *et al.* 2021). Hence, phase specific nuances are unlikely to be relevant. However, the media and mechanisms used for sharing information in project contexts can vary broadly depending on the individuals and functions or roles involved as well as the information shared (Ståhle *et al.* 2019). The media and mechanisms proved to be relevant for the effectiveness of the integration of interfaces between project actors and can range from meetings to IT systems to personal involvement to processes and rules. Therefore, it is crucial to develop reliable information flows that overcome the temporal and multi-stakeholder nature of projects (Lindner and Wald 2011, Sydow and Braun 2018). Due to the unique characteristics of disaster construction projects, this is even more relevant. Disaster construction projects overlay the requirements for speedy information to respond to the disaster that they are addressing upon the existing imperative to management information flows in projects. We posit, therefore, that understanding and managing information flows in disaster construction projects are crucial to responding effectively to that disaster.

Lean information flow

Given the role that this paper suggests for information flows in emergency construction project management, it is imperative to identify theoretical perspectives that can give insight to the ways in which those flows operate and their performance can be improved. Due to several advantages of lean, this concept has been applied to a wide set of organizational contexts. A useful theoretical perspective is arguably provided by "lean information flow".

Lean information flow is a distinct theoretical interpretation that involves transforming information flows with one specifically lean thinking: waste identification and elimination. In particular attention has been focussed on the construct of "lean information flow". The lean information flow concept is first formalized in Hicks's (2007) research. This research transforms lean thinking into information management and proposes five principles of lean information management (information value, information value stream, information flow, information pull, and pursuit of information perfection). As one of the crucial principles of lean information management, lean information flow is formalized as the manifestation of identifying and eliminating waste and plays a fundamental role in lean information management for information flow construction. By researching 10 companies with 250 employees, Hicks (2007) states four main wastes in information flow (excess flow, demand flow, demand failure, and flow failure), which correspond to the overproduction, waiting, processing, and defectiveness waste in lean manufacturing. However, no specific method has been suggested for how to implement lean information flow. Another research, which aims to create a model for lean information management, also states that the core principle of constructing lean information flow is to eliminate the waste in the information flow (Hölttä *et al.* 2010). It proposed seven wastes that should be identified and eliminated, which include waiting, conveyance, inventory, correction, defects, incompatibility, unnecessary transfer of information, and inappropriate systems. Ibbitson and Smith (2011) state that as one aspect of lean information management (another aspect is information value-added), the purpose of lean information flow is to identify and resolve issues around waste and uncertainty during the information exchange. Gîfu and Teodorescu (2014) suggest that lean information flow can be regarded as a method to eliminate information waste and increase information value to enhance the efficiency of systems. Based on Hicks's lean information flow waste catalogue, the study conducted in an automotive company provides practitioners with a reference for applying lean information, which specifically focusses on Muda identification and information flow obstacle detection (Bevilacqua *et al.* 2015).

Furthermore, aiming to validate the information flow concept in practice, Redeker *et al.* (2019) also integrate Hicks's waste model and seven wastes in manufacturing to identify and optimize the information flow in an emergency department. It also proposes that waste elimination can be regarded as the representative of lean information flow. Therefore, the construction of "lean information flow" can be formalized as the process of identifying and eliminating waste in the information flow.

Lean thinking identifies seven essential wastes in manufacturing – typically referred to as muda – namely overproduction, inventory, motion, defectiveness, transportation, overprocessing, and waiting (Womack and Jones, 1996). Overproduction occurs when operations should have been terminated and an excess of products is produced; inventory refers to all inventory that is held and directly or immediately required to fulfil customer orders; motion is concerned with extra movement by individuals caused by inefficient layouts, defects etc.; defectiveness is focussed on finished goods or services which are not in line with customer specifications; transportation is about non-essential movement of materials; overprocessing happens due to extra tasks such as rework, handling or storage and waiting is also termed queuing due to inaction in downstream processes. By integrating seven wastes in lean manufacturing and literature in lean information, we present a characterization of lean information flow (Table 2) that categorizes existing work in this area by relating it to the elimination of different forms of "waste" in lean information flow. It also provides explanatory questions against each waste category that can be used to ascertain the presence of lean information flow.

Lean information flows in disaster construction projects

A disaster construction project needs to be undertaken at pace. The disaster construction project delivery time will influence the speed that the damage of the disaster can be alleviated (Kalkman and de Waard 2017). This means that the delays in the disaster project will extend the influence duration of the disaster, which damages the organization or society more. It can be argued that the timely response and recovery of the disaster damage is the primary objective of the disaster construction project. Disaster construction projects normally have a considerable number of stakeholders due to the high degree of complexity of the disaster (Lagadec 2002). The disaster environment's complexity additionally requires multiple teams from different disciplines to collaborate for delivering construction projects (McLaren and Loosemore 2019). Given the swift variability and ambiguity in the disaster environment, teams cannot get sufficient, reliable, and clear project environmental information (Crichton *et al.* 2005) with implications for the ongoing project decision-making processes (Waugh and Streib 2006).

We argue, therefore, that when compared to the traditional project types, disaster construction projects are characterized by uncertainty, complexity, and, crucially, pace. Disaster construction project management is a project management milieu that aims to swiftly respond to or recover the disaster's influence by delivering some urgently needed goals, products, or services. In this context, we argue that speedy and accurate information flow is even more important in disaster construction projects than in traditional projects and that the nature of lean information flow, with its emphasis on waste elimination to enable speed and accuracy, provides a useful lens through which to consider information flow in disaster construction projects.

Research method

Research design

This paper follows an exploratory research design by adopting qualitative methods to collect and analyse data. Existing literature has revealed very limited theory combining lean information flow with temporary organizing in disaster construction projects but indicates that this research direction possesses elements worth probing. This study can be regarded as a response to an exploratory question based on such research status (Stebbins 2001). Swedberg (2020) indicates that due to the obscure research context in exploration studies, the research focus may continuously be developed through the data collection process. This means flexible and open-minded data finding and accessing play a critical role in this study. Compared to a quantitative approach, which strongly demands variable identifying and controlling, the qualitative method that does not need to follow the standardized data collection is more efficient in responding to an opening issue that stays in a new field (Fossey *et al.* 2002). Additionally, as this paper aims to study the practical usage situation of information flow in disaster construction projects, numerical data collected by the quantitative research method cannot comprehensively present the lived experience of the practitioner in this field (Lowhorn 2007). By

Table 2. The characterization of lean information flow.

Waste elimination type	Explanatory questions	Reference relating to "waste elimination" construct
Defectiveness waste elimination	Does the information flow only transmit accurate information? Does the information flow ensure that information received is information understood?	(Bevilacqua *et al.* 2015, Iuga *et al.* 2015, Redeker *et al.* 2019)
Waiting waste elimination	Does the information flow happen in a way to reduce the time that people wait to receive information? Does the information flow happen in a way that reduces the time that people take in transmitting information?	(Graebsch 2005, Gîfu and Teodorescu 2014)
Transportation waste elimination	Does the information flow avoid non-value-added conversions to different transmission medium? Does the information flow avoid arriving at the wrong destination?	(Hölttä *et al.* 2010, Soares and Teixeira 2014)
Motion waste elimination	Does the information flow eliminate the difficulties in information collection and access?	(Hicks 2007)
Overprocessing waste elimination	Does the information flow happen in a way that avoids unnecessary or non-value-added information processing?	(Gîfu and Teodorescu 2014, Bevilacqua *et al.* 2015, Redeker *et al.* 2019)
Over-production waste elimination	Does the information flow avoid multiple sources to deliver the same information?	(Iuga *et al.* 2015, Redeker *et al.* 2019)
Stock waste elimination	Is the storage of unnecessary information reduced? Is information loss whilst being stored avoided?	(Hölttä *et al.* 2010, Redeker *et al.* 2019)

employing the qualitative approach, researchers can connect with respondents to sensitively discover and collect detailed data that can depict practitioners' actual status in disaster construction projects (Merriam 2002). Hence, the data collected through a qualitative research design is appropriate for this study.

Data collection

The context of surge hospitals during the Covid-19 pandemic in the UK

This study chose the Covid-19 surge hospital projects as the disaster construction project context to collect data. The projects' primary purpose was to construct temporary hospital facilities for critical care or step-down care for patients recovering from a severe illness in diverse regions around the UK to react to the acute shortage of wards during the Covid-19 pandemic (Anandaciva 2021). These temporary hospital facilities were set up by retrofitting existing buildings such as local exhibition centres, which can provide sufficient space for bed arrangement. This project followed ProCure 22 (P22) contract. Participants were allocated two shifts to work between 7:00 am and 7:00 pm. The project delivery duration (which includes planning and construction time) for these hospitals, which ranged from 9 to 23 days, was accomplished in record time as showed in Table 3.

The projects were initiated by the Department for Health and Social Care (DHSC) with the National Health Services (NHS) in the UK representing the DHSC as the client. Restrictions caused by a nation-wide lockdown due to the pandemic, expectations of extremely fast delivery and complexities associated with building surge hospitals, led to the employment of numerous teams from diverse organizations and disciplines to cooperate in planning, managing, and executing. These surge hospital projects can be regarded as a representative disaster construction project milieu for this paper to discern project delivery practices. They exhibit all of the characteristics for a disaster construction project articulated in Table 1 and Table 4 gives further details.

Semi-structured interviews and sample

In developing this research, data was obtained by employing semi-structured interviews with the planning and delivery teams responsible for the surge hospital projects. The interviews were conducted shortly after the completion of the building works. Semi-structured interviews were chosen as the appropriate qualitative data collection technique as observations were not possible during this disaster situation. The retrospective nature of the interviews allowed participants to reflect on events and also provided some temporal distance from the extremely challenging circumstances under which the projects were delivered. Due to the Covid-19 pandemic, the interviews were conducted online to guarantee the researchers' and participants' safety. Each interview typically lasted

Table 3. List of the UK's temporary hospitals (Anandaciva 2021).

Hospital name	Location	Scope	Official opening date	Project delivery time (include planning and construction time)
NHS Nightingale Hospital London	ExCeL London	To retrofit the existing building and deliver 4000 beds for critical care	Friday 3 April 2020	9 days
NHS Nightingale Hospital Birmingham	National Exhibition Centre (NEC)	To retrofit the existing building and deliver 1000 beds for patients who need less intensive therapy	Thursday 16 April 2020	9 days
NHS Nightingale Hospital North West	Manchester Central Convention Centre	To retrofit the existing building and deliver 1000 beds for supplying oxygen therapy, general medical care, and rehabilitation services	Friday 17 April 2020	20 days
NHS Nightingale Hospital Yorkshire and the Humber	Harrogate Convention Centre	To retrofit the existing building and deliver 500 beds for critical care	Tuesday 21 April 2020	17 days
NHS Nightingale Hospital Bristol	University of the West of England (UWE)	To retrofit the existing building and deliver 1000 beds for Covid-19 patients	Monday 27 April 2020	23 days

Table 4. The UK Covid Surge Hospitals as disaster construction projects.

Disaster construction project characteristic	Presence in the UK Covid-19 surge hospital projects	Match to a disaster construction project? Yes [Y] No [N]
Purpose	Reacting to the need for hospitalization of large number of potential patients with Covid-19 symptoms	Y
Pace	Hospitals retrofits were required to be completed in less than a month which is extremely swift compared to more traditional construction projects	Y
Operation	During the Covid-19 pandemic	Y
Resource	Due to the nation-wide location, the logistic supply was blocked	Y
Multiplicity of Stakeholders	Stakeholders involved clinical staff, central government, a wide variety of National Health Service departments, local authorities, architects, principle contractors, subcontractors, the British Army, the general public and media	Y
Multi-Role Participant	Project teams comprised clinical staff, contractors, architects, sub-contractors and Army personnel	Y
Project environmental information	Given the unprecedented nature of the pandemic, scant information was available about the nature of patient that they were likely to receive and hence the functionality the project needed to provide	Y
Impact	Potentially extremely significance since the hospital facilities would be responsible for saving 1000s of lives	Y

between 45 and 75 min with multiple open-ended questions covering the nature, mode, and content of information transmission among intra- and inter-project teams. The semi-structured interviews furthermore allowed researchers to decide the interview direction based on the respondents' perception and experience about some pre-formulated main themes, which increased the flexibility of the data collection process to advance exploratory research in a new field (Kallio *et al.* 2016). It means that when researchers perceive responses that relate to the research objective, they can engender respondents to explain their feedback in more depth and ask to follow-up questions. This can be regarded as an interactive process where the researcher can guide interviewees to think deeply for some focusses to collect meaningful data. Interviewees may also replenish the details that researchers ignore, ensuring the validity and completeness of collected data (Schmidt 2004).

The sample for this study comprised individuals who were involved in the planning and delivery of surge hospitals in the UK. Due to the nature of the project teams, participants were employed across multiple projects at the same time, which can draw on their experience from more than one of the projects. In total this research interviewed eight project team members, who possessed abundant experience of surge hospital construction, with their details presented in Table 5. We believed that this sample had the potential to provide a sufficiently extendible sample given that the participants encompassed a diversity of construction project backgrounds and experiences and had worked on all of the

Table 5. Interview participants.

Interviewee	Role in the project	Covid-19 hospital project participated
A	Director/project manager	Nightingale Hospital London Nightingale Hospital Birmingham Nightingale Hospital North West Nightingale Hospital Yorkshire and the Humber Nightingale Hospital Bristol
B	Engineer principal/project manager	Nightingale Hospital London Nightingale Hospital Birmingham
C	Operation director/project manager	Nightingale Hospital Birmingham Nightingale Hospital North West
D	Construction site manager/project manager	Nightingale Hospital North West
E	Project manager	Nightingale Hospital North West Nightingale Hospital Bristol
F	Engineer principal/project manager	NHS Nightingale Hospital Yorkshire and the Humber
G	Construction site manager/project manager	Nightingale Hospital North West
H	Operation director/project manager	Nightingale Hospital London

Table 6. The prior template.

1. Defectiveness waste elimination
   1.1. The information flow guarantees the accuracy of information substance
   1.2. The information flow ensure that information received is information understood
2. Waiting waste elimination
   2.1. The information flow happens in a way to reduce the time that people wait to receive information
   2.2. The information flow happens in a way that reduces the time that people take in transmitting information
3. Transportation waste elimination
   3.1. The information flow avoids non-value-added conversions to different transmission medium
   3.2. The information flow avoids information arriving at the wrong destination
4. Motion waste elimination
   4.1. The information flow eliminates the difficulties in information collection and access
5. Overprocessing waste elimination
   5.1. The information flow happens in a way that avoids unnecessary or non-value-added information processing
6. Over-production waste elimination
   6.1. The information flow avoids multiple sources to deliver the same information
7. Stock waste elimination
   7.1. The storage of unnecessary information is reduced

Covid surge hospital construction projects. The fact that we were able to meet a "saturation point" with the responses from the interviewees paid testament to the adequacy of the sample.

Data analysis

The data produced from this study is in the form of interview transcripts. A template analysis approach was employed to identify the presence and nature of lean information flow in the transcribed data. Thematic template analysis is a distinct sub-discipline of thematic analysis. It involves operationalizing key constructs into an a priori coding template with a hierarchical construct based on the existing literature and preliminary understanding of the part of transcribed data is a critical phase in thematic template analysis (King 2012). We built our a priori coding template containing seven themes with ten codes using the characterization of lean information flow (Table 6), as illustrated in Table 2 in the previous section. The template approach has the advantage that not only providing confirmation of the presence (or absence) of deductive characterizations of constructs but allows researchers to get a holistic view of collected data enabling them to identify inductively some further areas they may not have previously intended to investigate (Waring and Wainwright 2008). As a particular thematic analysis form, template analysis with the feature of highly structured and targeted themes and codes is relatively efficiently employed in exploratory studies (King *et al.* 2018).

Findings

Coding the transcripts

By using a continuously iterative analysis that proceeded until all transcribed data relating to the research question was coded, this study employed the final template containing six themes and twelve codes, as displayed in Table 7. Compared to the prior coding template, the final one added one new coding tier (the third tier) with twelve new codes, and the original second coding tier became the sub-theme tier. The two sub-themes under the theme of defectiveness waste elimination and the two under the transportation waste elimination were merged into one, respectively. Therefore, the data presented all

Table 7. The final coding template.

1. Defectiveness waste elimination
   1.1. The information flow only transmits accurate information and ensures that information received is information understood
      1.1.1. Candid discussion pattern
      1.1.2. Transmitting information on-site
      1.1.3. High frequency updating
2. Waiting waste elimination
   2.1. The information flow happens in a way to reduce the time that people wait to receive information
      2.1.1. Limiting time for information generation
      2.1.2. Direct independent decision making
   2.2. The information flow happens in a way that reduces the time that people take in transmitting information
      2.2.1. Impromptu meetings and "real-time" sharing
3. Transportation waste elimination
   3.1. The information flow avoids not only non-value-added conversions to the different transmission medium but also information arriving at the wrong destination
      3.1.1. Highly structured information flow
4. Motion waste elimination
   4.1. The information flow eliminates the difficulties in information collection and access
      4.1.1. Employ co-ordinators for information sharing
5. Overprocessing waste elimination
   5.1. The information flow eliminates the difficulties in information collection and access
      5.1.1. Disregarding traditional project governance
      5.1.2. Streamlining information
      5.1.3. Collaborating using existing relationships
6. Overproduction waste elimination
   6.1. The information flow avoids multiple sources to deliver the same information
      6.1.1. Build the integrated information-sharing system

characterizations of lean information flow that constructed from existing literature, except the inventory waste elimination.

Despite the relatively small sample size we argue that we reached theoretic saturation in this coding process. Data saturation can generally be regarded as the point at which no new codes, themes, insights, or issues arise from analysing the data (Green 1999, Gaskell 2000, O'Reilly and Parker 2012, Glaser and Strauss 2017). This point is amplified by other researchers (Charmaz 2000, Morse *et al.* 2002) who argue that the replication in new data of themes and codes identified in older data is a signal for data saturation. In our data collection process, these forms of saturation occurred in Interviewee F (which is the sixth interview). We decided to conduct two more interview (Interview G and H) to ensure there is no additional codes or themes. All of the codes identified in Interviewee F, G, and H (in terms of "highly frequency updating", "direct independent decision-making", "collaborating using existing relationships" and "impromptus meeting") had been expressed in previous interview data. We concluded that our research had reached saturation and that further data collection was unnecessary.

It is important to remember that saturation is not related to the sample size. In qualitative research, saturation is provided by data content rather than the sample size (Saunders *et al.* 2018). The size of a sample cannot decide whether a study reaches data saturation or not (Low 2019). Johnson and Christensen (2019) argue that saturation is often reached in 6–12 interviews in case studies and Kuzel (1992) argues that 6–8 interviews are adequate in homogeneous samples. Morse (1994) indicates that smaller samples can reach saturation when the research objective is to comprehend the nature of experience. Our research aims to understand the project managers' experience of information flow in the UK's Covid hospital projects. We argue that this provides further evidence that our sample is sufficient to answer our research question.

The remainder of this section proceeds with the findings on the presence of lean information flow and illustrates the results of their corresponding effect on the project delivery.

Lean information transfer involving defectiveness waste elimination

Three codes derived from the transcribed data relate to the defectiveness waste elimination: *Candid discussion pattern*, *transmitting information on-site*, and *high frequency updating*.

Candid discussion pattern

This encapsulates comments on the honesty and collegiality surrounding information flow. For example, Interviewee E stated:

> I think it was a true sort of team effort from everyone involved. There was no hidden agenda by anyone. It was an open and honest, and sometimes brutally honest discussions to get the key decisions out from the clinician, from the end-users, and the consultants really (…) there was no sort of reticence from anybody. (Interviewee E)

Interviewee E commented that the purpose of "brutally honest discussions" is "to get the key decisions out from the clinician, from the end-users, and the consultants". The candid context for discussions promoted interactions between decision-makers and project teams. This in turn enabled decision-makers to correctly understand the project's real situation and led to better decisions. Thus, defective information flow was eliminated through honesty.

Transmitting information on site

Interviewee G emphasized that defect waste was avoided by ensuring that communication happened in person and on-site:

> Where you (…) a Teams meeting as well, on Teams meeting, I wouldn't have them because you can't get your point across. So, anybody who wanted to come on via Teams, I just say, "No. Unfortunately, I need you in person here". That's the pace we're going at. (…) It was best to be out there on-site (…) It was key to me that people came to site. (…) You can actually see what you're doing. And you're looking and you're saying "There's the electrician with a screwdriver in his hand, but he doesn't know where he's fitting. So, that's why I need you here". (Interviewee G)

> All of the supply chains directors were the people that were having some of these meeting with us out on site, not just leaving it with a site form (…) all the site supervisors were communicating on site, the collaboration was immense really. (Interviewee A)

> We're communicating on a daily basis with the local planning authority, the fire department were there every day, local police were on site pretty much all the time, so all the different bodies that we were communicating with literally on a daily basis, hourly basis sometimes, and it was face-to-face communication really and that was the key to everything really, just getting in people's faces and finding out what the drivers were. (Interviewee E)

> I think what helped as well to the ExCeL centre was a really good place where this because you open areas in the sort of in the conference suites where (…) you have big tables and you can get people around the table, this wasn't delivered by remote teams calls this was, people in the room, and actually that worked a lot better than expected to do stuff on remote cause with teams. (…) so, it was achievable. It was better than expected, it was faster and certainly eye opening, see what could be achieved when that sort of level of commitment, intent is there. (Interviewee H)

Compared to the effect of communication online or in writing, these quotes indicate that the effect of transmitting information on site is perceived to guarantee that the information sender comprehends the project's actual situation and provides accurate decision information for related participants. Defect waste in information flow is avoided by ensuring that accurate real-time information is provided for decision-making.

High frequency updating. Waste involved in transmitting defective information was also inhibited through high frequency updating of information flows:

> What we did was have every day, all subcontractors, everyone associated in the project had one session usually 4:00 in the afternoon where we share what we've achieved the day before and what the challenges were the following day … (Interviewee C)

> So we were sharing information, he would write a summary usually between 10:00 and 11:00 each night of all decisions we made that day, so when people either went to bed at midnight or when they got up at 6:00 in the morning, they would look at the teams update and have a very good understanding of what happened the previous day. (Interviewee C)

> They pushed the team to set up reporting meetings so we had meetings at 8:00 in the morning and at 5:00 at night (…) it was a drumbeat of meetings twice a day and the idea was that you'd have work stream leads that would report what was going on, would report any blocks, any risk to delivery. (Interviewee B)

> We would have a 10:00 meeting to say this is what I know, and I'll be saying to them this is where we are at the moment, and then I'd get each one of them to stand up and come to the drawing and point out what's happened in those area (…) And then that was then repeated at 2:00 so I could give another update of what's happened since 10:00 and 2:00 because a lot could happen, priorities could change and all the rest of it, so that's how it would be recorded. (Interviewee F)

> Our guys (…) they updated almost daily, and we set up a daily call between all of the project team so that we have that coordinated understanding of what the new. (Interviewee A)

Whilst participants' meeting times are different, all emphasized the adoption of a very frequent meeting schedule, usually at least twice a day, which is occasionally also supported by written summaries. However, verbal updates through regular meetings appeared to be the preferred way to share information, as written summaries could be outdated by the time they are read. Hence, frequently exchanging information ensured that information was free from defects associated with being out-of-date.

Lean information transfer involving waiting waste elimination

Limiting time for information generation

Waiting time waste was eliminated through the use of informal governance mechanisms which imposed strict response times:

> They'd have an input to it and their decision will be made within an hour of the design had been tabled. Whereas that process ordinarily could take a month by the time various people have been asked to comment. (Interviewee D)

> They wanted information very, very quickly. Every question that she was asked always seemed like the answer had to be provided within about two hours, (…) just keep the pressure on all of us, and to keep the information flowing in a good way. (Interviewee C)

> It was unique certainly in my experience of healthcare projects. The decision making was the key as well because people couldn't sit and ponder, the decision had to be made within minutes sometimes really, because it would hold up 500, 600, 700 men waiting for a decision on site. That decision making by the clinicians was really key to getting the job and keeping the job going to the exact timescales. (Interviewee E)

This suggests that the project team put in place the timeframe required for decision making based on the individual situation and the urgency of the project without consideration of traditional decision hierarchies. Wide stakeholder consultation was not regarded as a priority in this emergency construction project and hence, information generation was accelerated significantly.

Direct independent decision making

Waiting waste time in information flows was also eliminated by empowering the project teams to have the authority to make decisions. This was referred to multiple times by interviewees when discussing the information flow of decision-making:

> I'm going to make another rule and the rule is that if I can't get any of you to make a decision within one hour, I'll make it for you, and that was accepted by the client as quite a good way of making sure that I didn't allow them to slow us down and I didn't have to do it very often, and when I did do it a few times, they afterwards approve what I done anyway. (…) We can make things better and less expensive, if we allowed people a level of autonomy. (Interviewee C)

> I think everyone was a little bit (surprised) you know how quick the thing moved and realised that (…). there wasn't really an opportunity to challenge or to question decisions. I think they trusted our judgement that we would do what we said we'd do and get the job delivered but we couldn't sort of wait for someone to spend too long considering options A, B or C. (Interviewee D)

> There were emails, but it was mostly telephone call first because some of the decisions were literally minutes. I can't think of any decision where it lasted an entire day. It was literally, you know, we had to know something, or we had to have a decision on something, we'd ring the health board or a designer, or something like that, and we would have the answer back within an hour. And if we didn't have the answer, we just made the decisions ourselves based on the circumstances at that time, and then report back of what we've done just to make sure that everybody's aware of it. (Interviewee F)

These quotes demonstrated that if the project team could not obtain the decision information on time to continue their working progress, they would continue with their own decision-making anyway to impel the project development.

Impromptu meetings and "real-time" sharing

Project meetings were often informal and impromptu. This meant that they were extremely responsive and did not place "waiting" barriers on information flow in the project:

> The sort of meetings that we have are the impromptu ones, we managed to be able to hold these meetings where we would (…) get the right people in the room to make a decision, get it signed up, and everyone could move on. (Interviewee B)

> Yeah, I think in terms of communication you bring all these people together to do something in speed is completely at odds with how we normally operate and how do you get communication to everyone to make sure everyone was so, so there was a meeting drumbeat (…) impromptus report back by exception, yeah. get the relationships right keep it simple and have simple communication forums … if you needed to meet someone you had your separate arrangements to go through something with them. Yeah. That actually worked so smoothly (…) We have to augment that by, you know, share points, access to information, you know, getting a simple thing like getting a plotter and getting drawings out and plugging them and sticking them to warn so people could see (…) everybody knew what they should do so. (Interviewee H)

The interviewee described that these extemporaneous meetings streamlined the format of decision-making meetings into three steps, "get the right people in the room to make a decision, get it signed up, and everyone could move on". It means the project's decision information production process was simplified so that team members could get the instruction information swifter to continue their later tasks. Furthermore, the meeting form of gathering decision-makers for decision-making wherever or whenever also enhanced the occasions for stakeholders to communicate and discuss emergent issues. This situation was further enabled by "real-time" information sharing:

> That then led to even more collaboration … nurses that were assigned (…) they really did work closely with our teams all day and literally all night you know, we could

> be emailing them at 10:00 at night and they'll reply, but they work solidly with us to create what they felt was going to serve their requirements once these things are open. (Interviewee A)

> So, these decisions were made. The people who that impacted on in terms of what they were doing or what they needed to then go and do would have had that brief to them, again, in a very fast-tracked manner. (Interviewee D)

Real-time urgent information sharing had the same effect as impromptu meetings. People did not need to wait for organizationally imposed governance mechanisms to transmit information. They constructed an information channel that allowed team members to transmit information without waiting.

Lean information transfer involving transportation waste elimination

Waste involved in information flow due to onerous or ineffective distribution mechanisms and wrong destination arriving was also demonstrated in the covid hospital project context through *the highly structured information flow*. Information flows were formally structured to ensure efficient and effective dissemination:

> The majority of the 300 operatives I guess would have been guys and girls on the tails actually doing the work. (…) A decision had been made by the architect and the clinical staff and maybe myself on the delivery side of it. [It] would have been implemented through the various sort of levels of management down to the guy actually, you know, whatever knocking the door frame about and changing of a door within minutes. That would have been communicated down and the guys will be getting on with it. (Interviewee D)

This quote indicates that even though hundreds of participants simultaneously worked in the field during these projects, the information transfer was orderly. The information flow was constructed by identifying specific managers responsible for each project team handling and announcing the instruction messages. Managers could decompose information into separate components and send them layer by layer through the highly structured information transmission configuration to the downstream project delivery practitioners. Since the projects' information system allowed team members to accurately get the recent changes instruction produced "within minutes" from the upstream decision-makers to respond and propel their tasks, constructing the highly structured information flow can speed up the rate of change reaction and facilitate the project pace.

Lean information transfer involving motion waste elimination

Motion waste in lean information results when users of the information flow have to work hard to obtain information because it is in the wrong format, or they don't know where to find it. This was prevented in our projects through *the engagement of specific coordinators*:

> We have a lady (…) who was asked (…) to take on a different role during the [surge hospital] period and that was coordinating all the contractors for all the [surge hospitals] (…) if we couldn't find anything then she had contacts within the Department of Health who were charged with trying to source things quickly. (Interviewee C)

Some participants were employed by the projects as coordinators to be responsible for aiding each project team in information searching and sharing, enhancing the accessibility of demanded information. As this measure simplified the operation process of team members obtaining information, it could be treated as a motion waste elimination approach. The presence of information coordinators allowed project teams to save time on their activities, thus increasing project pace.

Lean information transfer involving overprocessing waste elimination

Information processing waste removal implies eliminating superfluous actions on information. Three codes extracted from the data can be clustered into this theme: Disregarding formal project governance, streamlining information, and collaborating using existing relationships.

Disregarding traditional project governance

This was exemplified by the following quote:

> One of the Army guys just said, "You just go on and do it". So, it was quite refreshing that you were given a bit of a license to – what's the right terminology? To sort of bypass some of the restrictions that we sort of have in place within the industry which probably there with good reason in terms of making sure that things are carried out safely and with due diligence. But when you haven't got the time (…) it was quite refreshing that they sort of trusted some of our decision making on the basis that we were long enough in the tooth. (Interviewee D)

> It was a very unique working environment. I think everyone senses that and it was quite refreshing in a way in that we were able to make decisions and implement those decisions without maybe having to write what pieces to justify what we were doing and why we were doing it. It was all done sort of with best intentions as it were. (Interviewee D)

Traditionally, in projects, decision-making processes are explicitly defined and potentially comprise the involvement of various parties. Managers need to spend considerable time explaining the decision and persuading to get the permission from stakeholders and hierarchies. Such arrangements were disregarded in this project context as they were perceived as inefficient and too slow to respond effectively to the emergency they were facing.

Streamlining the information

Waste in processing information was induced by streamlining it:

> I'd say the communication was really streamlined down to the finite detail. (Interviewee E)

It shows that the information communicated among different parties in the projects was "streamlined down" to only that which was necessary. Streamlining enabled quicker processing and added to the project pace.

Collaborate using existing relationships

Over-processing of information was also avoided by only working with existing collaborators using informal trust as a mechanism rather than formal contractual terms:

> With our supply chain that the guys who came and delivered the various works packages for us will have worked on and off with us across the last number of years. And they understood the urgency and there was an element of trust that they would be compensated for whatever their outgoings were at the time. You probably wouldn't have got that, I guess if we've had been trying to procure subcontractors who we didn't know from the next guy in the street. (Interviewee D)

> We developed relationships but some of them were known to each other, those that were in their early did have relationships, but you know what they probably knew more about each other. After that project than they did before. So, they had worked with each other, there's a certain amount of well I trust these guys (…) so there would have been people known each other. (Interviewee H)

> The people that were coming and doing millions of pounds worth of work, we had existing relationships and we as a business supply you know, like I said around a third of their annual turnover, so they understood that if I were asking to go and do something, they were going to get paid, they also understood they were taking a huge risk and leap of faith in the same time but nevertheless they did do that so there was a great deal of trust between us … (Interviewee A)

> People were selected for working on this project (…) they had existing relationships (…) I knew M (…) I think the team that were there on the Saturday, these are guys that had previous done work for AP at the RF states, so he knew, they were people that he had obviously confidence in. (Interviewee B)

> We picked who we wanted to work for or work with I should say based on our previous working relationship and knowledge of their competency expertise and enthusiasm. (Interviewee C)

The project teams chose to work with existing collaborators in order to avert the information processing waste. They perceived that "there would not have been the time to engage with a non-familiar supply chain" in the project's emergency environment. The existing trust saved the time that conducting communication for cooperation relationship building and urgent situation comprehending. Compared to collaboration mode with new suppliers, coordinating with familiar ones can simplify the communication process of the project supply chain, meeting the urgency of the specific project context.

Lean information transfer involving overproduction waste elimination

Lean information processes remove waste through the avoidance of duplication. This type of waste elimination was found in a number of situations in our project context and is represented by building the integrated information-sharing system. Project manager C emphasized the significant role of the projects' information-sharing system in achieving high degree collaboration:

> So, C and A from [client] worked closely with each other to talk, communicate, make sure that all the lessons learned and data available was being communicated across each of the contractors that were working on [surge] hospitals across the UK. (…) C was talking to into serving Birmingham, and whoever was doing Manchester and whoever was doing Harrogate, and making sure that everything that we could learn, that was being shared across each of the businesses and when it came to key decisions about availability of anything, there was somebody there who was trying to coordinate what was. (Interviewee C)

This shows a widespread information system that shared the project experiences from diverse regions

constructing surge hospitals. Because of this approach, whatever barriers were overcome quickly by sharing information across the industry in these projects. It implies that this information system saves time for different project teams by effectively sharing information on lessons learnt.

Discussion

The findings of this paper show clear qualitative evidence for the information flow in the UK's Covid surge hospital projects avoiding "waste" in terms of defect, waiting, delivery, movement, overprocessing and overproduction. The a priori template characterizing lean information flow (that we produced on the basis of existing literature in this area) was successfully populated with empirical exemplars from an analysis of the interview transcripts. Thus, we feel justified in asserting that the UK Covid surge hospital projects utilized lean information flow. This is an important finding. Before embarking on this investigation, we had no evidence of the type of information flows that were taking place in disaster construction projects. Our findings suggest that the adoption of an information flow perspective is beneficial to the effective delivery of disaster construction projects. Furthermore, the utilization of lean information flow enabled the project teams to share information, reach decisions and communicate at unprecedented speed. The lean flow of information in this context was associated with the overall impressively speedy completion of the UK's Covid surge hospital projects. On a prima facie basis, therefore, it appears that adopting lean information flow in disaster projects would lead to much speedier delivery times for those projects. Given the importance of pace in disaster construction project delivery, this finding has ramifications for disaster project management in a wide variety of contexts.

Such a claim would, however, requires much further consideration. Speed is only one measure of project performance, and it depends on the primary objectives of the project if this measure should become the predominant one. In certain disaster situations this might be the case, but it cannot be universally assumed. The sole focus on speed can come at cost to other measures, and the leanness of information flow could lead to situations which were harmful to the holistic delivery of these projects. One of the advantages of the template analysis approach we used in this project is that, in addition to the structured identification of characteristics that enabled us to identify lean information flows, it also provided insight into the context in which lean communication was employed. Whilst not formal "findings" of the research, this does provide us with a basis for reasoned speculation, which we will explore in this "Discussion" section.

Lean information flow did not always result in a holistically "best" project delivery for the UK Covid surge hospitals. The empirics gathered by this research provide tantalizing glimpses of situations where the decision-making may have been speedy but was prejudicing other project delivery outcomes. For example, the emphasis on using existing relationships, as exemplified by Interviewee D statements, provided no opportunity to develop relationships with other actors. Thus, projects could not avail themselves, for example, of other suppliers which could have provided cheaper solutions with more functionality. Lean information flow also seemed reliant upon a great deal of autopoietic governance. Actors made up their own processes and procedures rather than recognizing or abiding by organizationally sanctioned project governance. The phenomenon within UK Covid surge hospital projects of ignoring organizationally sanctioned governance structures being associated with speedier project delivery does demand further investigation. But the ability to ignore formal governance procedures, especially those surrounding considerations of risk and stakeholder engagement, does imply that lean information flows may not have been completely beneficial to holistic project delivery. Interestingly, the later experience of the UK COVID surge hospitals bears this finding out. The hospitals were never used at any level of capacity because of shortages of staff to operate them and the changing needs of patients making their functionality obsolescent. Arguably, better adherence to existing project processes of risk management and stakeholder engagement may have ameliorated this situation. The tendency of a "lean" approach to becoming "anorexic" is a construct well established in the operations management literature (c.f. Cusumano 1994, Eroglu and Hofer 2011) and may equally apply to information flow in disaster construction projects.

A further potential explanatory phenomenon following our template analysis was the apparent role of trust as a potential and necessary condition for lean information flows in disaster construction projects. The willingness to employ lean information flow depended upon trust: trust gave actors the confidence to bypass or ignore organizationally sanctioned governance mechanisms in its pursuit. Trust was frequently called upon by project actors in describing situations where they had by-passed organizational project procedures

(c.f Interviewee #D "I think they trusted our judgement", "it was quite refreshing that they sort of trusted some of our decision-making", "there was an element of trust"). We speculate that the willingness to create autopoietic governance in support of lean information flow was possible because of the high levels of trust between project actors. Trust has previously been identified as a vital component for information and knowledge flow in projects (Brookes *et al.* 2006). Trust is also regarded as a crucial strategy to avoid information asymmetries between construction project teams (Schieg 2008). Based on the trust, project participants believe they pursue a common objective in the project, so they would request and share information candidly and transparently, which allows them to promote the information flow and then solve related design management issues in construction projects (Uusitalo *et al.* 2019). Besides, trust is also significant in the more general context of disaster construction projects (Kalkman and de Waard 2017, Vahanvati and Mulligan 2017). Frequently the type of trust associated with temporary organizing in this milieu is "swift trust" (Pollack and Matous 2019), a construct identified by Meyerson *et al.* (1996) and defined as "a unique form of collective perception and relating that is capable of managing issues of vulnerability, uncertainty, risk, and expectations". Swift trust does not rely on the existing relationship but on actors acting if they trust one another and only "untrusting" if their actions justify it. In the context of the UK Covid surge hospital projects, actors did not employ swift trust, instead electing to work with each other on the basis of pre-existing trusting relationships. This empirical finding contrasts with work which places swift trust at the heart of disaster construction project management (McLaren and Loosemore 2019). We also speculate that the reliance on trust was increased, if not engendered, because of the project's disaster nature. In a non-disaster project, the risk of using autopoietic rather than organizationally sanctioned governance to support lean information transfer may be deemed too great. This nexus of trust, governance and information flow is worthy of much greater theoretical attention in understanding how temporary organizing should be conducted in a disaster. This nexus been neglected as Levie *et al.* (2017) in their investigation into project governance for the Haiti Earthquake Disaster point out where they state that "project management literature provides little by way of the insight into the relationship between governance and trust".

Finally in this section, the extendibility of the findings of this investigation beyond the UK Covid surge hospitals to the wider consideration of temporary organizing in projects needs to be considered. In Table 4, we derived exemplar characteristics of disaster construction projects to which the UK Covid surge hospitals conform precisely. However, Table 4 did not differentiate the nature and degree of uncertainty. It could be argued that, in the context of the UK Covid surge hospital projects, the core objective, namely retrofitting a building to give it a different functionality, was a task that had been carried out before albeit not in disaster circumstances. This does have implication for lean information flow as it allowed existing relationships to be called into play in disaster projects. It is possible to conceive of disaster construction projects where there are no pre-existing relationships at all. It would be interesting in these circumstances to see if there was a re-emphasis on externally imposed, rather than autopoietic governance, in the construction of project information flows. However, routinized tasks do lie at the heart of disaster construction project responses for our findings to have applicability on a wide population of disaster project responses.

Conclusions

Fulfilment of the research aim

The aim of this investigation was to investigate the role of lean information flow in the effective delivery of disaster construction projects. In order to achieve this aim, we conducted qualitative research with a sample of actors responsible for the delivery of the UK Covid surge hospital projects. We operationalized the construct of lean information flow by characterizing it as the elimination of different forms of "waste" based on more traditional lean frameworks employed in manufacturing. We found substantive evidence that lean information flows were being used in the disaster construction project context to support decision making and enable speedy project delivery. However, we also found tentative evidence to suggest that lean information flows were potentially inducing more inimical outcomes for disaster construction project organizing and that employing lean information flow depended upon a context of trust and acceptance of risk that is peculiar to disaster construction project organizing. We concluded that the context of the UK Covid surge hospitals was sufficiently exemplary for our findings to be applicable to other disaster projects.

Contribution to theory

The application of theory to disaster project organizing is nascent. Our study has made a number of theoretical contributions which were presented in the "Discussion" section of this paper. Firstly, through its empirical findings, this research has established a link between information flow and project delivery speed. This supports existing research work that posits that an "information flow" lens is important to understanding the disaster project organizing phenomenon. Furthermore, our work has contributed to and generally supports the body of work on "lean" project management by demonstrating that "lean" is a useful construct through which to consider project information flow. This has been achieved by articulating a framework that characterizes the application of lean thinking to information flow in projects and providing empirical support for the theoretical assertion that using lean information transfer speeds up project delivery.

Secondly, we have posited a complex nexus of relationships between constructs of "lean", "trust" and "governance" that underpin lean information flow in disaster construction projects and speedy project delivery. This is based upon emergent empirical phenomena, and it is fair to say that our theoretical contribution in this context is largely one of making explanatory demands on existing theory. This is especially true since our empirical findings appear to lie orthogonally with extant work on trust in disaster projects (c.f. McLaren and Loosemore 2019).

Contribution to practice

The current political, societal and environmental context appears to show that disaster is becoming endemic (Roitman 2021). Given that project organizing is the manner in which most disasters are responded to, our work has particular resonance for project practitioners. Our work indicates that practitioners need to be aware of information flows as an important factor in enabling speedy decision-making in disaster projects. Furthermore, the framework for characterizing lean information flows that we derived (shown in Table 2) provides practitioners with a mechanism by which to evaluate the information flows within their own disaster construction projects. This will enable practitioners to make information flows "leaner" and hence speedier. No other frameworks are available that can be used in this context.

Limitations of the research and future research directions

Albeit we determined that our findings were extendible, we acknowledge the limitation of conducting our investigation in one particular cultural and sectoral context. It would be very interesting to conduct a similar investigation in wider disaster project contexts to see if similar findings to ours were found. Additionally, given the links we have found between the constructs of "trust" and "lean" on information flows in disaster construction projects, quantitative research, perhaps utilizing structural equation modelling, may be useful to investigate this phenomenon further. Our identification of the substantive role that lean information flow can make in speeding up disaster construction project delivery is justification for much further investigation in this area.

Disclosure statement

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

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