

The Role of People and Data in Complex Spatial-Related Long-Term Decisions: A Case Study of Capital Project Management Groups

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Abstract—Significant long-term investment projects can involve complex decisions. These are often described as capital projects and the factors that contribute to their complexity include budgets, motivating reasons for investment, stakeholder involvement, interdependent projects, and the delivery phases required. The complexity of these projects often requires management groups to be established involving stakeholder representatives, these teams are inherently multidisciplinary. This study uses two university campus capital projects as case studies for this type of management group. Due to the interaction of projects with wider campus infrastructure and users, decisions are made at varying spatial granularity throughout the project lifespan. This spatial-related context brings complexity to the group decisions. Sensemaking is the process used to achieve group situational awareness of a complex situation, enabling the team to arrive at a consensus and make a decision. The purpose of this study is to understand the role of people and data in the complex spatial related long-term decision and sensemaking processes. The paper aims to identify and present issues experienced in practical settings of these types of decisions. A series of exploratory semi-structured interviews with members of the two projects elicit an understanding of their operation. From two stages of thematic analysis, inductive and deductive, emergent themes are identified around the group structure, the data usage, and the decision makers within these groups. When data were made available to the group, there were common issues with the perception of veracity and validity of the data presented; this impacted the ability of the group to reach consensus and therefore for decisions to be made. Similarly, there were different responses to forecasted or modeled data, shaped by the experience and occupation of the individuals within the multidisciplinary management group. This paper provides an understanding of further support required for team sensemaking and decision-making in complex capital projects. The paper also discusses the barriers found to effective decision-making in this setting and suggests opportunities to develop decision support systems in this team's strategic decision-making process. Recommendations are made for further research into the sensemaking and decision-making process of this complex spatial-related setting.

Keywords—Decision making, decisions under uncertainty, real decisions, sensemaking, spatial, team decision making.

I. INTRODUCTION

CAPITAL projects are significant long-term investments and can involve complex decisions when combining factors such as: budgets, the reasons for investment, the range of stakeholders, interdependent projects, and the impacts of construction and the product [1], [2]. The complexity of these projects can be measured [3], [4]. For this study, the projects

gain complexity from the interconnectedness of their components [2]. Complex strategic decision making often requires management groups to be established involving stakeholder representatives, these teams are inherently multidisciplinary with the expected advantage of an increased knowledge pool [5]. This study uses university campus capital projects as case studies for this type of management group. Project Management Groups (PMGs) are created at the university to deliver the project through to completion, and it is the representative members of two of these PMGs that the study will be conducting semi-structured interviews with. One of the buildings was an expansion to accommodate more collaborative academic work for a multiple-school research institute. The second building was a humanities-oriented teaching and student study space to meet a judged lack of space in the associated schools.

The university campus infrastructure and range of users means that decisions are made at differing levels of spatial granularity over a capital project. Spatial contexts introduce complexity to decision making in groups [6]. Combining this with the range of backgrounds and experience of team members, there is a need for clear focus and goal priority for projects as found with similar projects in the literature [7].

It is suggested in some research on success factors of project management that that the human factors are woven into management factors leading to decisions [8]. This paper explores the people as well as the data and decision making to try and understand how well the human dimensions are connected into the group operation.

Sensemaking is the process to understand complex situations, when carried out successfully it enables the team to arrive at a consensus and make a decision [9]. For a team, it can be the process through which they try to explain the situation and anticipate potential future states [10]. We treat sensemaking as the process of reaching situational awareness as a product, which provides understanding in complex or uncertain situations in order to make decisions. Previous research has used the sensemaking perspective as a way to study the decision-making process and the strategies employed during the process [11].

Of particular interest in understanding complex spatial-related long-term decisions and the sensemaking processes is the trust in data and decisions for collaborating groups [12].

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Research has demonstrated that there is a role of the larger institutional setting on individual projects and it is also a resource in the team decision making [13]. In multidisciplinary team meetings there is an influence on discussions of the expertise of individual members during discussion, this can direct the mapping of roles and responsibilities of individuals in the team onto the decision making [14].

The paper aims to further identify and present problems experienced in practical settings of these types of team strategic decision making. The research offers a case study of opportunities to support factors such as coordination in projects and consensus reaching in team decision making [15], [16].

This study aims to understand the structure of the sensemaking and decision process for significant development projects on campuses, and the extent to which data are used to achieve this. In an effort to identify opportunities to intervene and support team sensemaking, the study investigates the following research question: "To what extent is data used in the group sensemaking and decision-making process for significant development projects?"

II. METHOD

A. Data Gathering Process

Participants were recruited from the PMGs of the two most recently completed buildings on the main university campus to take part in semi-structured interviews. The semi-structured format was appropriate for the limited number of participants accessible for the interviews and would provide reliable and comparable data [17]. This would enable interviews to follow a general guide of questions, while allowing for different paths that emerge from interviewees to be pursued in more depth. The goal of the interviews was to gain a qualitative understanding of the team members' experiences and views from the projects.

Six interviewees (3 from one project, 2 from the second project, and 1 who sat on both PMGs) represented a varied set of roles at the university including heads of school, directors within the university senior management, and capital project managers.

Interviews were held virtually using Microsoft Teams meetings, and followed broadly six areas of questioning:

- An introduction to the participant to understand their role at the university outside of the PMG, the extent of their experience with capital projects, what they understood their role in this team to be, and whom/what they saw themselves representing.
- Framing of the project that was being discussed by summarising the purpose of the build as they understood it, this meant the driver(s) for the build, the target users, and some of the impacts and needs considered during the project.
- The wider working processes of the group such as the meeting frequency and format, the nature of discussions and decision-making involved in the project.
- The extent of data use by the team during discussions and the decision-making process, any data generated by the group during the project, and the format of presentation for

either of these types of data.

- Further detail on the working method of the group, how they collaborated, and tool use in discussions or presentations.
- A reflection on unforeseen challenges and their resolutions, desires from the participants if the project were repeated, and experience they carried forward to current/future projects.

Sample supporting documents were also sourced from the managing group of the PMGs, the university Estates Office, these included terms of reference, and meeting agendas and reports for both projects represented in the study. These would be combined with written notes and the transcriptions from interviews for analysis.

B. Data Treatment/Pre-Processing

Written notes were collated from interviews that managed references in interviews to extra material such as PMG reports and the terms of reference. Interview transcriptions were anonymised, and unrelated sections were removed such as disruption from the interview during the call. These were then exported to Nvivo as the data corpus for thematic analysis.

Thematic analysis was carried out following a reflexive approach [18]. The first stage was in vivo coding, this was driven by the theoretical interest in the areas explored by the interview questioning, and by the initial research questions on how PMGs operate and how they could be supported. A list of initial codes was generated by a series of read throughs of the interviews, familiarisation with the data, and emerging patterns were documented to begin developing themes for the second stage. The level of theme identification reflected the areas of questioning in the interviews, with overlap appearing in responses being grouped into themes such as the discussion of data available and in the reflection of participant desires. These preliminary codes and themes then became subthemes to three emergent main themes relevant to the research questions. A second stage of coding was then carried out, this time deductive coding using these emergent themes and subthemes from the inductive process. Allocating data to these defined themes generated a list of codes, and produced relevant data extracts that were able to be presented to demonstrate the emerging themes.

III. EXTRACTED THEMES

The three themes and the 12 subthemes generated by the analysis were:

People:

- Representation
- Future occupants
- Decision makers
- Subgroups and related group
- Gatekeepers and experts

Data

- Data types
- Presentation and visualisation
- Data flow
- Trust/validity/veracity

Decision

- Decision flow
- Granularity
- Tools

Broadly these cover the makeup of the PMGs and their degree of multidisciplinary, the extent of and opportunity for data use, and the nature of the discussion and decision making for these projects.

IV. THEME 1 - PEOPLE

Theme 1 explores the makeup of the management groups, whom/what these people represent, who is attached to the group, and what the role of members are.

A. Representation

The university capital project management teams are designed to be representative of the stakeholders for the capital project, and so the groups are inherently multidisciplinary. The degree of representation is determined through the managing group of university PMGs, the Estates Office, and the Chair of the group. This method using the experience of the Estates Office should capture most stakeholders, particularly the target end users of the building, but there is potential to miss representation of more removed or indirect stakeholders, such as campus visitors.

Some team members have a firm understanding from their own perspective of why they are part of the group:

“...it has my staff in it, and it’s connected to one of our other buildings.” and “...my role was definitely to represent the school...bring forth any particular issues, of which there are quite a few that relate specifically to [us].”

For one participant it was about what they were there to represent too:

“I represent the students and the academics, and the university financially...I know how many academics need wheelchair space, I know how many have got childcare so have to work until 7 o’clock at night that sort of thing...So it’s the data really, maybe I represent the data.”

Many members identified what they believe was a primary reason for their membership of the team, commonly that related to their job title at the university, though they also saw themselves as fulfilling an additional role alongside this:

“I was there for two reasons, one to provide continuity...the idea was that there’d be a permanent member of staff to support the [Student Union] officer view, and the officer view would be the view of students or would be the representation of students...My view was more of a critical, operational, you know how are we going to do this, what are the impacts of this going to be.”

“My involvement in the BDI project was twofold really, one was representing the IS (Information Services) infrastructure side of it, but also to look at okay that building came from having a really big ambition, and to make sure whatever that ambition was, it was translated into decision making around what was in the building.”

B. Future Occupants

The most directly involved groups can be very clearly seen for a project, often driving the lists used to pulled together the management team members, these are the groups that all participants in the previous section identified themselves as representing. However, the concept of future occupants or users, and the expectations of involvement can be disjointed within team, or between the group and the stakeholders. One of the buildings was going to require a physical interface between the new build and an existing building. When considering the impact on those that would not be occupying the new build, participants often drew attention to awareness of how the building would fit into its place on the campus:

Neighbours of one of the new sites could also have had their deliveries impacted “...there’s some big limitations now on turning circles of trucks, so it’s limited the size of trucks that can get to certain parts of that bit of the campus. ...what does that mean for people, does that mean they have to have more deliveries...”

A notable issue for both occupants and non-occupants was amenities. These buildings do not operate in isolation, they will either provide a service and will therefore draw non-occupants, or they do not and the end-users will need to seek out amenities and services elsewhere, usually in nearby buildings:

“...there needed to be greater consideration around what are these people going to do to eat when you suddenly parachute another 300, 400 people in.”

A particular issue highlighted in one of the projects was around cost implications for the new build and impacts for the future users. In one case the make-up of the future occupants and their activities could have large implications for VAT. For those not moving into that building there were cost implications for reconfiguring the old space that was being vacated to ensure it was suitable for them. Achieving this understanding of future occupancy and use can be difficult but significant in decision making:

“...probably the biggest work in terms of the Project Management Group which then fed into the actual implementation group really is what the loading of people was going to look like, what the distribution was going to be between schools.”

“...that would generate income through obviously having undergraduates there, so that was clearly teaching but what they hadn’t realised that was undergraduate research projects from other schools would also take place in the building.”

C. Decision Makers

The flow of decision making and way the teams work is explored in more detail in Theme 3, but here the extent to which the group are the decision makers in the project is considered.

In some instances, the group clearly acts as the decision makers for the project, such as choosing the specification of the IT systems going into the buildings. As seen in the representation subtheme and in formation of the group membership, the managers of the team, the Estates Office, can act as the decision maker as opposed to the group. In discussing

the decision on room sizes for one of the buildings, the Head of Estates at the time chose to increase the sizes to give some leeway for future class sizes.

There were several decisions highlighted that related to the running of the project, the building as a process, rather than the end product. The team was able to act with autonomy to shape this building process. For example, on choosing where to make space for contractors:

“...there was an idea I had right at the very beginning which was to stick the builders into the underground car park because they were going to put lots of huts in front of the Boots building.”

There were examples of decision influencers emerging in the group for topics that related to their role of representation or expertise, where the rest of the group may be non-experts and ratified a decision rather than making it. This will be explored further in the next subsection, but Information Services presented an instance that they took on a role of decision influencers:

“...that was one of the important decisions because that had knock on impacts to the trunking, you know whether its optical fibre, copper, whatever these are kind of very technical things but the decisions that were being made about the research led to impacts on the building...”

PMG members could be upskilled though to be able to act as decision makers alongside the experts:

“...[there is a] complexity of the university and the regulatory environment that we need to operate in, so I’ve learned a lot more about the sort of specific building regulations, environmental impacts statements and policies, and how that drives some very significant decision making.”

In one of the projects, future occupants were made decision makers having had their choice narrowed by contractors and the management group. The stakeholders had more direct involvement but through a curated list of colour schemes and branding options for the new building.

D. Subgroups and Related Groups

As seen in the previous subtheme, there are instances when decisions can be made or influenced by a stakeholder rather than by the group. This stakeholder was often part of a subgroup associated with the main representative team and would take on roles including fact-finding/justification projects, or were part of the wider planning structure of the university. The capital projects operated within a network of management teams at the university, meaning the group operated within meeting cycles of major university committees. The subgroups had a degree of autonomy when feeding into the main project group:

“The biggest work in terms of the project management group which then fed into the actual implementation group really is what the loading of people was going to look like.”

Participants acknowledged that these related subgroups were often used for decision making and then feeding back into the central group for ratifying decisions and discussions throughout the project:

“I think that particular decision was probably done offline.”

“I think that was done slightly outside of the PMG but it certainly was brought back to the PMG to be kind of discussed and noted.”

This overlapping of subgroups can cause some participants to struggle to separate the roles and the activity, and the purpose of the management group:

“What you found was there were a lot of meetings outside of meetings...certainly there were separate meetings about specific topics but all the big items were discussed in PMG.”

“I’ve got to be sure it definitely happened at PMG and didn’t take place somewhere else.”

In the instances that these offline decisions are made by subgroups it is unclear to what extent the team could then scrutinise the decisions in their role of ratifying them.

E. Gatekeepers and Experts

In their roles as representatives of a stakeholder group many of the participants were to an extent an expert in an area of discussion for the project. Some of the team members acted in the capacity of a gatekeeper to data or to access a user group. The group managers, the Estates Office, were one of two notable groups whose representative was a significant expert and gatekeeper for discussions. Sitting between the university, contractors, and consultants the Estates Office recognise themselves as the conduit, experts and gatekeepers:

“...arguably we’re the ones who have more knowledge across the whole project if you like.”

“...not an overseeing role but a sort of making sure the right information is getting at the right times to the group.”

The other notable related group was the university finance committee:

“All these PMGs have a representative from Finance...they’ll basically say look you can’t do that, or you won’t be able to do that or this will need approval, that’s their job.”

Participants recognised that experts were also involved from future occupant groups for reasons such as understanding of health and safety zones. In some cases, the members recognised themselves as the experts or gatekeepers to help the team understand detail of how much teaching would take place in a building or space on campus, or evidencing the need for single occupancy offices:

“I lead the team who build all the timetables for the university and who run all the exams for the university...I know and I can get the data for what areas of campus are going to be busy with what sized groups.”

F. Theme Summary

This theme highlights the varied makeup of the teams, multidisciplinary representatives of many stakeholders in these two projects. The exact membership of this group is determined through appointment of a Chair by the university Estates Office and generation of a list of representatives by the Terms of Reference. This process generates only an initial list of

stakeholders, and it is clear as projects develop and are modified the list changes as true stakeholders that were unaccounted for emerge. The interviews revealed a strong connectedness of campus user groups and interdependencies between the future occupants of new building projects and the extended list of other stakeholders. It was common for participants to describe how different groups would be interested in not just the new space that was coming but also the space being vacated, and the space vacated by those that take that space up, and so on. This created significant interdependencies when considering ramifications of decisions about the new space.

The collaborative setting demonstrates well the connectedness of a population in space and its use. There is a spatial relationship between these campus users, their buildings, and users beyond just occupants such as campus visitors and deliveries. They interact with each other either intentionally or not. This is highlighted and will be discussed in the decision flow subtheme, but the connectedness can be demonstrated by the amenity discussions. These buildings do not operate in isolation, they will either provide a service and will therefore draw non-occupants, or they do not and the occupants will need to seek out amenities and services elsewhere, usually in nearby building. Introducing a new building, rather than redeveloping an existing one, certainly increases the number of people that will be in that space on campus. This increase needs to be considered with the capacity of the local and wider campus area. This could be in terms of amenities, or related to travel such as parking options, bike spaces, and accessibility.

Needs for, and impacts on, future occupants and non-occupants should be covered through a combination of representation directly in the team, involvement in subgroups and related groups, and through experts in the group. The extent of offline decision-making or conversations described by participants suggests that this representation is not ideal, stemming potentially from the identification of stakeholders stage. These offline discussions can be concerning for the team, responsible for delivering a project they need to be able to scrutinise and understand decisions that have been made on their behalf or outside of the group. This could be most challenging in the case of indirect stakeholders, where a user group that's ultimately not going to use the building will be impacted by project decisions. An example is the space that is expected to be vacated as a result of the project and how that will be used. The end users of this vacated space have a keen interest in the decisions made about the new space because one influences the other. There was evidence of missing input from a future occupant group in one of the projects, a participant indicated no one seemed to have spoken to the performing arts group about their needs for one of the spaces being designed. This demonstrated an issue in the identification of stakeholders and the measures taken to gather their input on requirements for the project.

The roles assumed by team members are fluid during a project. The multidisciplinary nature of the groups means individual members change their role within the same project depending on the demands of the group. They can take on the role of expert in the area they represent or be a gatekeeper to

data for use in discussions. They could be brought on as a future occupant, but then act as a representative for a related group of non-future occupants because of their role at the university. Members can be tasked with data/fact finding for discussion as a sensemaking step to the group decision making. These mixed perspectives offer a challenge in how individual members and the group can scrutinise decisions in their role of ratifying them, or in exploring data to arrive at a decision when they have the autonomy to make one. Through sensemaking using relevant data, members could be upskilled sufficiently to act as decision makers alongside those that were initially described as experts. For certain topics of discussion and decisions being made some members moved into a role as a decision influencer, trying to steer discussion of the group ultimately to a particular decision point. This behaviour was most often seen where the discussion was most closely linked to a role a team member initially identified in the interview as their purpose in the group.

This theme reveals in many respects that the PMG acts as a central hub for the stakeholders in a project, and can be a well-situated mechanism for discussing and deciding on aspects of capital projects at the university, bringing together stakeholder needs and perspectives in assessing decisions.

V. THEME 2 – DATA

Theme 2 explores the extent to which data are currently used by PMGs during a project and opportunities for further use of data. It also looks at some characteristics of the data that are used such as ownership and the trust in the data, and how it is presented.

A. Data Types

Across the projects it was apparent that data are used in the discussions and decision process, many of the same types of data are used across different builds. The most prevalent types align with the role of the management group and the nature of the buildings that each group was tasked with.

All participants indicated the extent to which the future occupant data were used in their decision making. This is expected as they are tasked with a building project to meet a need for a set of people, and the quantity and makeup the occupants would influence the solution that meets that need. The source of these data and the granularity of it varied. For one of the buildings the need being met by the project was focussed on teaching space and capacities, this meant that a significant source of data used was the university timetable data. This data source was able to provide indications of the current situation on the campus, detail on the people, and the spaces they would be using, and led to decisions such as class sizes needed:

“...the data for what areas of campus are going to be busy with what sized groups, how popular, you know what size lecture theatres, what size seminar groups, how many how busy places are going to be, how many labs they've got that sort of thing.”

“...we had lots of data on space usage...Yeah its class sizes and things like the percentage of, what I did was the amount of classes that I had to send to other areas of campus...And the amount of time waste walking

backwards and forwards.”

The timetable and future occupant data brought with it a spatial component, demonstrating some of the ways that the team could consider the project as part of a wider picture of the university campus, or in one case the city-scale situation for the university. Mentioned by nearly all participants was the amount of car parking before and after the builds, including the detail of different type of parking space that would be available. Similar to the data above, the car parking was often discussed in a spatial nature, relating the spaces that would be available to nearby buildings and landmarks. Here there is indication of related meta data to car parking, the walking distance from target buildings. This was not explicitly captured but indicated a further spatial element to the data type that was considered by some team members.

In discussing cars both groups also covered flow of traffic in the nearby area of campus and the impact of the new building and the construction on that traffic. Traffic flow of pedestrians was also covered by all participants. This will be explored in sub-sections to follow, but data were not used explicitly in either of these scenarios where the team discuss potential impacts of the build or the post-completion effects. These present a clear opportunity for collection and use of data to show the current situation and augment discussion on impacts.

The combination of vehicle traffic, car parking, and pedestrian flow combined for one participant and their concern for modalities of transport and the impacts of the build. This example will be returned to in the subtheme of decision flow in the next theme, “...if that is well we’re gonna reduce the amount of parking space but increase the headcount and people will just have to use other transport approaches.” But they were not convinced that sufficient alternative modalities existed or at least were not supported properly for the number of people they were expecting to introduce to the area with the new build. On talking about pedestrian flow, two participants indicated a more abstract element to the pedestrian data and its spatial component, this was the idea of pleasantness of walkways and environmental data such as noise levels and greenery.

The building process itself also highlighted data usage: underground service plans, furnishing and equipment mapping, project cost and project time. Each of these projects is assigned a budget and has constantly updated costs for the build which each decision could impact. Equally each project has a schedule for delivery, and milestones, with impacts for each decision.

B. Presentation and Visualisation

This theme highlights the ways data are presented to the group for discussion, and may demonstrate how the data that are not collected or used could be incorporated.

The most common tool for sharing data with the group was written reports, circulated ahead of every meeting, these were used particularly for the operational data highlighted in the previous subsection (time and cost). With these reports came more detailed data relevant to the discussion and decisions for that scheduled meeting in an addendum of papers with the headlines pulled into the main report. This addendum often included papers put together by the members such as evidence

for the use of single-occupancy offices or the timetabling situation for future occupants.

Maps and building plans were presented to the group to aid discussions and to highlight some of the data being used. The maps were mostly restricted to service plans and construction impacts, while the floorplans would be used to highlight detail throughout the building. Maps and floorplans did not mean many data were being presented to the team, participants described that pedestrian and traffic flow would be highlighted with a couple of arrows of different sizes.

In terms of tools to present any data in the meetings, the circulated report displayed on a screen was used along with PowerPoint presentations to guide discussion and decisions:

“There were presentations, we used Teams, so there was a Teams so everything was accessible so to be honest people were there with their laptops or iPads or whatever they were going through the documents live, there would be reports, I mean just the typical presentation either a pdf or a PowerPoint.”

“We’d normally put the PMG report up on the screen as well in that room, just to make sure people could look at it and actually focus people onto particular elements.”

C. Data Flow

Considering the data that were available to the teams, and the ways they were presented with it, this section looks at where the data that were used came from, such as instances of when team members would need to provide the data.

The university and project leads, the contractors and Estates Office, were owners of data related directly to construction such as building plans and underground services. The management group as a collective generated data that were used in their discussions, this was centred mainly on the future building occupants and use. Individual members of the PMG also acted as sources of data, tasked by the group or Chair to provide some data as evidence for use in decision making from their position as an expert or representing future occupants: “I was asked for some evidence...I provided how much teaching time would take place.”

The meeting reports were often a main source of data flow into the group:

“...what you got was an update on progress, you got an update on the finances every, you got a risk assessment to go through, a key milestones, a standard I would say a standard project report which is basically updated the group on the decisions that had been made, the actions that had been taken and any decision that was requiring the groups input.”

There was significant flow through the group as the team communicated outwardly to the stakeholders and to related university committees they operated within: “I can remember quite a lot of discussions about when meeting dates were and how it was important to get this data to that group.”

D. Trust/Validity/Veracity

This section now asks to what extent members trust the data in their discussions, if they can scrutinise one of the pieces of

evidence presented for a decision made.

After one participant acknowledged most data were fed into the group, it was not clear whether it was always accepted at face value or challenged. A different participant described how this attitude may have changed over time depending on the source of data:

“I think when I came in the faith in timetabling was quite low at the university...people didn't understand timetable data back then, people didn't want timetabling data back then, but now our data is in such a good state that we're actually using our data as a source of truth for things like campus solutions.”

The range of accuracy of data available to the group was exhibited by two examples of specific technical data from the earlier and later construction phases on the same project:

“The university no longer has accurate plans of the services, underground services.”

“...we were then able to have technical teams go through literally room by room workout where every single power socket would go, internet socket, every item of equipment was mapped out in place and so the level of detail was phenomenal.”

There was a desire to be able to challenge presented data more, particularly where it had been used to justify a decision:

“I think what would be useful in all projects is to test the validity of assertions, particularly around space usage...there's a theoretical usage and an actual usage.”

Though PMG members were able to acknowledge that the data were not always valid, there were mixed responses on how that was dealt with, and how the data could be questioned. The issue of the underground services data highlighted above was remedied through several ground surveys to provide accurate data. This time to remedy inaccurate data were not always available. Space usage and occupancy illustrate the interaction of provenance and veracity of data being used in the team decision making. This is a data type being used for evidence in decision making but participants disagreed on whether it is accurate data being used, and their levels of trust in the data used and the conclusions varied:

“...yeah I'm surprised that I've not been asked to review it...But I'm guessing that if the space utilisation technology that we put in is working correctly then I wouldn't need to, so maybe they're getting it from there.”

“...the occupancy levels aren't great and what we installed in Teaching and Learning Building was a sort of infrared room checking device or whatever it is, apparently it doesn't work so well.”

A contradiction for some participants was particularly apparent discussing the accuracy of their data and how much it could be trusted in sensemaking or as evidence for decisions. Combined with the occupancy technology above, one PMG member explained:

“I can get the data for what areas of campus are going to be busy with what sized groups, how popular, you know what size lecture theatres what size seminar groups, how many how busy places are going to be, how many labs they've got that sort of thing”

While two described how and why there is a lack of trust in that type of data used:

“...we did a quick and dirty usage analysis a couple of summers ago round that and we reckon that no more than 50% of the rooms that were being booked were actually being used.”

“...of teaching bookings probably about 70% were being used and the meeting room bookings, about 50% were being used...Now that's a massive waste of space when I'm saying look at all these bookings we need new buildings.”

People movement both inside and outside buildings was another type of data that most participants agreed had a degree of fuzziness to it, and therefore the questioned the validity of a diagram showing predicted flow:

“...if you try and get from say the security station that or the cut through to the Pharmacy building up the road towards Trent and so on, if you try and get from there down to the QMC bridge there are so many different ways you can walk.”

“People don't understand that you're in a lecture theatre of 300 people and 300 people could go 300 different ways.”

E. Theme Summary

This theme has shown that there is large range of data types that can be used by these management groups, and the availability to them albeit limited in some cases. There are staple data types that are common across these capital projects. For the operation of the group these include the timing of the meetings, related committee schedules, build progress and forecasts, and financial data for the build as both an isolated project and as part of the larger university structure and budget.

Future occupant groups and numbers, transport modalities and car parking people flow in and around these buildings featured in discussion from all participants, but with disagreements. It was not consistent across or within projects the extent to which data present was questioned, whether valid data were driving a discussion, and the extent to which they trusted the data or the conclusions.

As a data type in decision making, future occupants featured heavily in exercises of group members to provide numbers. The final occupants are negotiated throughout the project and so it must be questioned how much these figures at each stage of the project can be relied on or how uncertainty can be managed. This highlights some issue in: the data gathering exercise; the scrutiny of the future occupant data claims when presented; and how well the delivery of the project aligns with the planned occupancy. Consideration needs to be put into how team members can build trust in an important sensemaking data source if their experience is preventing them from trusting it.

Both projects presented scenarios where there was a question about the trust in how or where the data had been generated, and the veracity of it for use in discussions. This trust could be influenced by metadata such as the provenance, commonly it was guided by the individual's experience at the university. Most of the data are not interactable for the group. The

presentation method and flow of the data made it difficult for a member to interrogate the data or test any assumptions. For some of the participants this may have been acknowledging the fuzziness of the data type. There was a desire to be able to test assertions either with data or assertions being made of the data.

Timetabled occupancy data presented a case for expectation versus reality and the validity of data in sensemaking and data-driven decisions. One participant described how it is being used as a source of truth but there is disagreement between at least four participants as to if that is valid data. Historic room surveys demonstrated 30-50% error on room usage against what was booked. Participants also agreed that for example a timetabled room for 100 people often is not filled with 100 people, at least not for every session it is timetabled over a term or year. If there is this mixed level of trust in the veracity of some data, what is the impact on the team sensemaking, and on the decisions that are made?

Looking at the discussions around space usage, there was evidencing of requirements using two different sources, timetables or installed sensors, that differed. These conflicting multiple sources demonstrate an opportunity for use of metadata, namely around provenance in this case, to allow team members to establish data quality and negotiate the truth as part of their sensemaking discussion.

Cost presented two types of data that could interact. The forms of cost included in meetings covered both historic and predicted type data. This parallel of forecasted project costs/budgets and eventual spend could reveal useful data by tracing with the project timeline to identify significant deviations from prediction to reality. This could then feed back into the project or into subsequent capital projects on the campus.

There is a clear opportunity for introduction of grounded traffic and pedestrian flow data, it connects into the modality of transport. These are not just projects on the inside a building, but the building in situ, embedded in its surroundings, the rest of campus and communities beyond such as commuting occupants and visitors.

VI. THEME 3 - DECISION

The third theme investigates the PMGs as decision making units. This considers the nature of the decisions that are made by the group, those that are made for the group, the granularity of these decisions, and the tools used to aid decision making.

A. Decision Flow

The PMG as a body sits among subgroups and wider university governance, and as with data, there is a degree of flow of decisions into and out of the group. They are not the single decision-making body on a capital project, but have the capacity to make a number of decisions during the process. These projects are created within the Estates Office and with university senior management to address one or more issues. Work is done by groups external to the PMG before one is formed, with a problem identified and proposed solution pulled together by the capital project team within Estates Office and some other stakeholders:

“We went through all the committees last year with a

business case and presented it, and eventually we got to Estates and said right we’re at a stage, we want to progress it further, we need a PMG convening.”

Responses did demonstrate that the team had the capacity to make decisions and influence change in decisions that were made earlier in the project or before the group was assembled. This was often driven by presenting evidence compared to an original case put forward:

“The lecture theatre was originally planned to be a size 120 interactive lecture theatre and we looked at interactive lecture theatres and thought they’re brilliant however there is no need for a size 120 within the area.”

Within meetings the Estates Office representative would often highlight the potential impact of decisions the team could make, both on the building program and the larger strategy at the university for its capital projects:

“...there’s a lot of attention to that part of it, the program and how, if we make this decision what impact is it going to have on the program.”

As with the data involved with the discussions, many of the decisions had their flow dictated by other more permanent groups within the university governance structure. The team may make a decision, but it could need approval, and therefore evidencing.

In terms of how decisions were arrived at, the Chair of the group mostly led a discussion around the issue for contributions and questions from group members until there was sufficient agreement. The discussions would be a sensemaking exercise for the team to understand the issue being addressed and the solution(s) being assessed, then work towards consensus through presenting data and papers in the reports, and discussion in the room.

B. Granularity

There is a range of granularity of decisions that the group can make on what the building looks like, the feel of it, and how it would work fundamentally. Even if the decisions in isolation are specific, it was demonstrated that the group does have to consider the project program and the broader strategy for the university, and the impacts of decisions on these. The decisions made at the most granular could cover exact space use and equipment both in and around the site:

“...not just that so for example do you want tablet-top tables in your lectures theatres, for example do you want how many left hand and right hand ones do you need, because of how many students are left handed and how many students are right handed...And if a left handed student gets a right handed one will it compromise them or will they complain, you know those sorts of conversations you get into quite granular detail.”

Stepping back from exact furnishings in rooms, the groups did determine the usage of the rooms and the way this would influence the users:

“...so the discussions around that were about not just the physical layout of the building but how can we naturally make it easier for people to have those accidental conversations.”

At the broader level, the big items as described by participants were decisions that had the biggest impacts on the project and the implications of those decisions:

“The biggest issues we dealt with were things like the tax which was a big thing because that was a you know a million pound plus decision and the bridge had to be built very long between the two bits of CBS BDI, planning permission and things were complicated.”

“...shown certainly at some point early on how the general philosophy of the university’s campus plan was consistent with what they were doing, so there’s long term plans for that portion of the campus.”

Most concerns regarding decisions being made by the group were focussed on the immediate surroundings of the building, the neighbouring buildings. Participants indicated that the group did not always achieve the right considerations across the levels of detail for decisions made, that could affect both future and non-future occupants, such as the environmental factors and the student experience of the building. Influencing the granularity of decisions was the frequency of meetings, on average once every 2-3 months. There were disagreements between members on recalling the frequency, and this may relate to the fuzziness of the groups and its subgroups and related committees.

C. Tool

This final subsection explores the extent to which tools are being used by the teams as part of the decision-making, and indications of desire to use tools to support their discussions and decision-making process.

Bringing forward the methods of data presentation, participants portrayed the reports and presentations as tools, both as sources of evidence for decisions and steering for discussions in that meeting. One participant highlighted their use of a vision document as a tool for the group to assist in the conversations about the space use in the project, it summarised what they understood the identified problem and project as the solution to be. Maps were used across both projects, both presenting to the group members, and in one project as part of the discussion on pedestrian flow in the area with decisions being made based on that.

It was apparent that some forms of data were used as a tool for the team decision making. These included the timing and financial data when considering impacts of decisions on remaining project schedule or budget, and often when covering issues on space occupancy:

“That’s a fundamental thing of any decision we make so we have to make sure that if we’re say, if we say to the PMG you can have pink carpets, but it’s going to add 3 months to the program they need to know about that before they make the decision...same for costs, if you want pink carpets it’s gonna be half a million pounds extra.”

Across all participants there was a clear desire for more data as a tool for decision making in the group:

“What I would have liked was the ability to challenge, with data, saying okay well this building is intending to provide X number of rooms totalling this capacity, what’s

our evidence that we need this and that were not just inefficiently using our spaces at the moment.”

One of the participants also stressed use of tools to better engage the stakeholders, communicating decisions made as well as making them:

“This group had a website...there was lots of communications, so good communications, particularly in projects like this impact upon lots of different people.”

One representative showed a desire for a more in-depth reflective post-occupancy evaluation as a tool, enabling predicted data used in one project to be validated and able to inform future projects using the same or similar data sources.

D. Theme Summary

This theme highlighted the variation in perceptions of the management groups in their purpose and operation, and a number of opportunities to support the groups in carrying out the decision-making task as part of a broader strategy.

There was inconsistency in the understanding of which decisions are made for the team and they operate to ratify, which they are able to make with a degree of autonomy, and which decisions they can make that will also need to be passed to subsequent groups for approval. For the decisions that were made outside of the team there was an appreciation for the role of subgroups, future occupants and experts being given more control over the process, but it was ambiguous for some members as to the role that left them with, or how the decision fitted with a strategy they may not be aware of. When carrying out the task of ratifying these premade decisions, the groups had in some cases challenged with evidenced arguments and altered the decision for the project, but would have liked to scrutinise more of them. This interdependency of operating groups within the university structure means that although a capital project may take a number of years to complete, there is a low degree of pressure put onto the decision making for the teams to maintain the pace for other committees or boards.

Some of the most granular decisions such as furnishings were made with the most autonomy as a group, with use of financial and construction program data of the project to understand the ramifications for decisions. The largest decisions that were made by the group involved the most interaction with related groups and an extended series of approval. These showed a much broader consideration for the strategy of the university, the motivation for the project, and the building in relation to its locality on the campus.

Whether or not the group was operating as a decision-making body or in ratifying a decision made for them, it was clear that there is an opportunity for greater use of data as a tool to enhance the team sensemaking process, to understand fully the issue they are resolving and the decision they make. Through this data driven decision-making they could also enable better assessment of assertions, and approval or recommendations for change, and eventually communication of the decisions.

Whether the group was making a decision or ratifying one, they commonly had to start by undergoing a team sensemaking process to understand the situation and demands, to be able to appropriately act. This is continuous throughout the project as

it develops. It is important that the team members know the problem(s) being solved by a capital project, as it forms a significant driver in decision making and is a frame for goal-oriented sensemaking. Given the length of these complex projects it would assist joining team members to have a common basic framing of the identified problem and initial proposed solution. The vision document described by one participant presents an interesting sensemaking tool as a shared review of the “current” situation.

Participants highlighted multiple times the desire to challenge decisions or assertions with data, as an example wanting a clearer view of the future occupants. This points back to the need for accurate data. In the cases of asserted and eventual occupants of one build, and on student timetabling or space monitoring technology, participants demonstrated a scepticism around some data sources. For different reasons, some participants did not think the data they were using was accurate, therefore they did not trust it and did not have full confidence in the decisions made using those sources. There is a challenge then to provide data as a tool to these groups to enable the team sensemaking and decision making while engendering trust in that data and subsequently the decisions. These meetings have some tools (tablets and laptops) already available that could be used differently. Currently used to follow reports and agendas, they could also have access to interactive data, exploring as a team but also individually to interrogate before making a decision.

The teams did not function through voting on decisions, instead moved discussions towards a shared consensus to make a decision. This suggests a greater degree of shared sensemaking required rather than the case of a group voting approval of decisions. In the voting scenario individual members could reach their own conclusions on seeing papers/data presented, make their decision and cast a vote, while a Chair aiming for group consensus requires more explicitly shared understanding and discussion. This discursive process to reach consensus may also lend itself to being more iterative and encourage scrutiny of assumptions or assertions.

VII. CROSS-THEME SUMMARY

There was a theme across the participants of a discrepancy between the expected or reported and the reality, such as timetable data for generating requirements and surveys of booked room usage in existing meetings. With this difference in claimed or assumed needs and evidence or knowledge of a different reality there is a degree of trust lost in the data used and the decision made. These assertions can be, and in some cases were, questioned by individuals, and discussions followed around this with the experts and other PMG members.

The operation of the team seemed most smooth when the flow of decisions and members involved matched the granularity of the discussion, properly representing future occupants and considering the implications on the neighbouring area and the longer-term strategy.

The acceptance and interpretation of assertions and any information presented varied across experts and non-experts in the areas. Certain roles, if they were tasked with evidence

gathering in a report or were respective experts on the topic, were the gatekeepers for different decisions and data. Each member had their own perspective of the role of the project that was shaped by their experience with other projects, their role outside of the group within the university, and their awareness of concurrent projects and wider strategies for the campus.

The discussions about future occupants for a building highlight a number of shared issues in the themes. Groups did not want to know the name of every researcher or student that would be moving into or using the building, though they wanted to know the future occupants to build for. Research groups fluctuate in size, occupancy levels for lectures and booked rooms were up to 50% wrong, and attendance at lectures is not the same as the timetabled capacity of a module. These future occupant numbers were incorporated into the collaborative sensemaking and decision making on room sizes, equipment, and impacts on the surrounding area with pedestrian flow, transport modalities and amenity needs. This highlights some issue in: the data gathering exercise; the scrutiny of the future occupant data claims when presented; and how well the delivery of the project aligns with the planned occupancy. Consideration needs to be put into how team members can build trust in an important sensemaking data source if their experience is preventing them from trusting it.

VIII. CONCLUSION

The capital projects explored in this study and their management groups offer significant opportunities for greater data usage in a team sensemaking and decision-making environment. This study also suggests similar benefit could be found exploring other capital project examples. With respect to the initial research question on their operation and the extent to which data are used there were a few key findings.

In cases that data were made available to the group, there were commonly issues with what was available, issues of accuracy highlighted by future occupant lists changing throughout the project that were incorrect still at the point of staff and students moving into the building. In many cases there was a desire for data from participants to enable them to test assertions or decisions being made.

In most examples reported by the participants the data used in discussions and arriving at a decision were not interactable. The presentation and visualisation methods made it difficult to interrogate the data or test any assumptions, and this contributed to some ambiguity for members as to the purpose of the PMG and the decisions it was able to take during the project. Though some tools for interacting with data were available in meetings such as the tablets being used to follow the reports, consideration should be given for this interaction by individuals and the team impact the collaborative sensemaking process.

One of the projects demonstrated that ambiguity in data impacted the decision-making process, reducing the confidence or satisfaction in the final decision. This asks the question of how transparency with the fuzziness or the veracity of data can change the confidence in assertions from the data or decisions reached? There is potential from enabling deeper questioning

of assumptions and data for individuals and the team to have increased satisfaction in decisions made.

Trust can be engendered in data sources used during the sensemaking process. From the examples of student occupancy and timetabling in the interviews, this trust could be engendered through provision of metadata, highlighting characteristics such as provenance, allowing the individuals to make assessments of the data quality. Future work could consider the impact on the confidence of individuals and the team making decisions and communicating them to stakeholders.

The spatial-related context offers an opportunity for richer presentation and visualisation methods for data, which could better support the sensemaking process and decision making for the team. In a multidisciplinary team setting, with varied expertise and perspectives of decision makers, more work is needed to understand how an increased accessibility to and interaction with data changes how people perceive the data as a tool for decision making. In addition, work needs to be done to recognise how awareness of different characteristics of data affect the perception of validity and veracity, and the trust in data for use in the discussions.

In settings such as the projects explore in this study, a team needs to achieve consensus with these multiple sources of data and perspectives. They need to be able to interact with the data, assess its quality and interrogate assertions, ultimately engendering trust in some of the data, reaching a shared sense of situational awareness, and making a decision. Some of the most granular decisions such as furnishings were made with the most autonomy as a group, with use of financial and construction program data of the project to understand the ramifications for decisions. The largest decisions that were made by the group involved the most interaction with related groups and an extended series of approval. These showed a much broader consideration for the strategy of the university, the motivation for the project, and the building in relation to its locality on the campus. For capital projects with institutional framing to the complex team decision making there is more work that can be done to understand the relationship between the granularity of decision and the decision process. This would direct the sensemaking support requirements for these such as data treatment and presentation.

REFERENCES

- [1] A. P. C. Chan, D. Scott, A. P. L. Chan, "Factors Affecting the Success of a Construction Project", in *Journal of Construction Engineering and Management*, vol. 130: 1, 2004, pp. 153-155.
- [2] B. Xia, A. P. C. Chan, "Measuring complexity for building projects: a Delphi study", in *Engineering Construction and Architectural Management*, vol. 19: 1, 2012, pp. 7-24.
- [3] Q. He, L. Luo, Y. Hu, A. P. C. Chan, "Measuring the complexity of mega construction projects in China – A fuzzy analytic network process analysis", in *International Journal of Project Management*, vol. 33: 3, 2015, pp. 549-563.
- [4] Y. Lu, L. Luo, H. Wang, Y. Le, Q. Shi, "Measurement model of project complexity for large-scale projects from task and organization perspective", in *International Journal of Project Management*, vol. 33: 4, 2015, pp. 610-622.
- [5] V. Dayeh, B. W. Morrison, "The Effect of Perceived Competence and Competitive Environment on Team Decision-Making in the Hidden-Profile Paradigm", in *Group Decision and Negotiation*, vol. 29, 2020, pp. 1181-1205.
- [6] K. Vincent, R. E. Roth, S. A. Moore, "Improving spatial decision making using interactive maps: An empirical study on interface complexity and decision complexity in the North American hazardous waste trade", in *Environment and Planning B: Urban Analytics and City Science*, vol. 46: 9, 2018, pp. 1706-1723.
- [7] C. Scott-Young, D. Samson, "Project success and project team management: Evidence from capital projects in the process industries", in *Journal of Operations Management*, vol. 26: 6, 2008, pp. 749-766.
- [8] T. Cooke-Davies, "The 'real' success factors on projects", in *International Journal of Project Management*, vol. 20: 3, 2002, pp. 185-190.
- [9] P. Pirolli, D. M. Russell, "Introduction to this Special Issue on Sensemaking", in *Human-Computer Interaction*, vol. 26: 1-2, 2011, pp. 1-8.
- [10] G. Klein, S. Wiggins, C. O. Dominguez, "Team Sensemaking", in *Theoretical Issues in Ergonomics Science*, vol. 11: 4, 2010, pp. 304-320.
- [11] U. H. Richter, F. F. Arndt, "Cognitive Processes in the CSR Decision-Making Process: A Sensemaking Perspective", in *Journal of Business Ethics*, vol. 148, 2018, pp. 587-602.
- [12] M. Suprpto, H. L. M. Bakker, H. G. Mooi, W. Moree, "Sorting out the essence of owner-contractor collaboration in capital project delivery", in *International Journal of Project Management*, 2015, vol. 33: 3, 2015, pp. 664-683.
- [13] T. Dall, S. Sarangi, "Ways of 'appealing to the institution' in interprofessional rehabilitation team decision-making", in *Journal of Pragmatics*, vol. 129, 2018, pp. 102-119.
- [14] A. Lanceley, J. Savage, U. Menon, I. Jacobs, "Influences on multidisciplinary team decision-making", in *International Journal of Gynaecological Cancer*, vol. 18: 2, 2008, pp. 215-222.
- [15] J. G. Gerald, G. Adlbrecht, "On Faith, Fact, and Interaction in Projects", in *Project Management Journal*, vol. 38: 1, 2007, pp. 32-43.
- [16] M. Jelokhani-Niaraki, J. Malczewski, "Decision complexity and consensus in Web-based spatial decision making: A case study of site selection problem using GIS and multicriteria analysis", in *Cities*, vol. 45, 2015, pp. 60-70.
- [17] Bernard 1988 R. H. Bernard, "Research methods in cultural anthropology", Newbury Park, Sage Publications, 1988.
- [18] V. Braun, V. Clarke, "Using thematic analysis in psychology", in *Qualitative Research in Psychology*, vol. 3: 2, 2006, pp. 77-101.