THE ROLES OF REPRESENTATIONS IN BUILDING DESIGN: MATERIALITY AND VISUALISATION

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Mock-ups, scale models and drawings are ubiquitous in building design processes, circulating between various stakeholders. They contribute to the gradual evolution of design, but what else can specific material representations do for the building design and project? The full scale model of a hospital single bed room can be different in terms of detail and medium, but in what sense might it perform different and similar functions? The mobilization of multiple forms of representations and visualizations suggest that design materialization might have several important roles to play in negotiating the building design and project, including in the exposition and resolution of controversy in the design process. The paper compares the use of two different forms of representation of the same imagined space – a single room in a hospital, and produced for similar purposes – to ascertain what the optimum (or minimum) spatial requirements should be to allow effective care of patients. The first representation is a three dimensional augmented reality model of a single room for a new hospital in the UK, using a CAVE (Cave Automatic Virtual Environment) where the room is reproduced virtually at one-to-one scale, and which can be explored or navigated using head-tracker technology and a joystick controller. The second is a physical mock up of a single room for a Danish hospital where actual medical procedures are simulated using real equipment and real people. Drawing on Latour's concepts of matters of concern and matters of fact, we compare these two representations to provide insights into the way different media produce specific senses of the design or imagined space, with consequences for on-going design work, and for the settling of controversy.

Keywords: simulation, hospital design, matters of concern,

INTRODUCTION

The cover image of the book 'Reassembling the social' (Latour, 2005) depicts a construction site with the people, equipment, building material and scaffolding. Front stage, two men are having a conversation over what seems to be a document, perhaps it is a plan or a drawing for a building. Behind them and closer to the perimeter of the construction site, several armed soldiers keep a watchful eye on the surroundings. The

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building site seems controversial and many human and non-human entities are required to hold the project together. When the building has been completed it might be used and taken for granted by people that pursue their own projects. From Latour (2005) we can say that the building has become a 'matter of fact'. However, the author urges us to consider the building as 'matter of concern' rather than as a 'matter of fact', i.e., as an ongoing accomplishment; from its inception, during construction and in use. A building "is not a static object but a moving project" (Latour and Yaneva 2008, p.80). As a matter of concern the building and project is never finalized. The concept 'matter of concern' is in line with actor-network theory's (ANT) questioning of the fact/value distinction in the social and natural sciences and the assumption that objects such as a building can be represented in a value neutral manner.[3] Technologies of representation and visualization are not just considered as neutral and passive (Latour, 1986). Rather the ANT approach puts emphasis on revealing the more active role of technologies in shaping designs and in enacting and negotiating design options, users and use. Designs are matters of concern that are distributed and produced in heterogeneous networks consisting of both humans and technologies (Latour, 2008). The approach has been used to examine building projects and topics such as; visions and goals (Harty, 2008; Tryggestad *et al.* 2010), design practices (Whyte *et al.* 2007, Yaneva, 2005; Våland, 2010), innovation (Harty, 2005), business performance (Justesen and Mouritsen, 2009; Kjellberg, 2010) and the relative visibility and difference between building design and integrated chip design (Kreiner and Tryggestad, 2002). In this paper we will examine different forms of representation and visualization and the ways in which they participate in negotiating the hospital building as 'matter of concern'.

METHODS

Our inquiry is built around two cases on the concept and design of a "single bed patient room" in hospital building projects in UK and Denmark respectively. The approach is processual and aims to reconstruct the complex chain of events concerning the design. The collection of empirical material involves in the first case visits at the design lab and design exhibition at Region S, reports and images documenting the design process, and interviews with members of the project management offices, including project management at Region S and Region H. The data for the second case is a combination of attendance at design meetings, informal interviews with the project team, and a series of video-recorded and direct observations of design review activities within a virtual reality facility at the University of Reading.

While both cases are emerging we present preliminary findings concerning how different technologies of representation such as 2D, 3D and full scale 4D 'physical' simulation models participate in the materialization and valuation of the single bed patient room design. Both cases account for the simulations and demonstrations of how large the room should be, the further design requirements of other things such as equipment and furniture that emerges in the design process, and finally, the different materialities that participate in constituting the room and designed space.

[3] Evidence based design (EBD) is a relevant example of an approach that seeks to turn facts into design, with the potential downside that matters of concern are ignored or not taken sufficiently into account.

CASE 1: HOW LARGE SHOULD THE ROOM BE? THE DANISH SINGLE-BED CONCEPT

The Danish state has established a program ('Kvalitetsfonden') with approximately 40 billion DKK dedicated to fund hospital construction projects within the public healthcare sector and regions. It is one of the largest societal infrastructure investments in Denmark, ever. Currently there are some 16 hospitals on the drawing board or under construction within the programme. The projects are of different types, ranging from mega projects such as the large green field investments in new 'super hospitals' within the major cities and regions in Denmark, to upgrading of existing hospitals. Each hospital project within the program must pass the state's screening body, the 'Expert panel'. It is an iterative process through which the region's original project proposals are evaluated and eventually refined before dedicated funds are allocated to a hospital project. The case of the Danish single-bed concept consists of two vignettes that reconstruct the evolution of the design concept and the related concerns and controversies. The first vignette accounts for the Expert panel's concept and evaluation of the single bed patient room. The second vignette shows the different ways the design concept is enacted and negotiated between the regions and the Expert panel. Together the two case vignettes show how the single bed concept is represented, visualized, re-conceptualized and negotiated through time and space. The case description accounts for different devices such as numeric calculations/budget estimates, comparative case analysis of different types of rooms and sizes, full scale physical mock-ups and how these individually and together validate the design concept in relation to future use and users.

Economic valuations of room size: The hospital program and budget

In their report the Expert panel (Regeringens ekspertpanel 2008) considered the design of the single bed patient room in terms of how large it should be. The expert panel did not question the premise and value that the room should be a single bed rather than a multi bed room. Instead, there were further considerations about the maximum size. The room should not be too large because that will incur unnecessary costs both to the individual hospital's project budget as well to the future hospital facility and operating budget. The expert panel's future budget concerns are further translated into an estimation of the appropriate size for the single bed room: 40 square meters is considered too large, and 33-35 square meters is considered appropriate, for all hospitals and projects in the program. In order to qualify their estimation of the appropriate size and design standard, the expert panel uses a production cost calculus for the construction of a single bed room that demonstrates the economic effect of a too large 40 square meters room. The economic calculations of the production costs and the two cost budgets (for the project and hospital in operation respectively) help the expert panel to explicate the value of a cost efficient hospital design and to define its appropriate size. The question and concern about the appropriate design and size is thus resolved through the economic calculation and the budgets. The report further helps to visualize this economic design value. More implicitly, the single bed concept also takes other values and concerns into account such infection risks and the prospective patient's need for privacy. However, and to be further described below, these different design values and concerns are only temporary resolved by the Expert panel's economic calculations and report.

Juxtaposition of clinical and economic valuations of room size

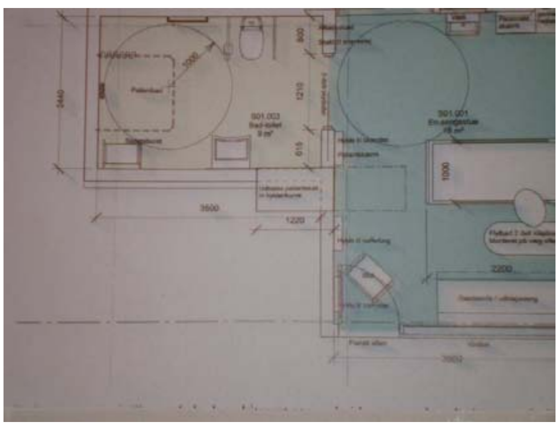
At the Capitol region a project team was established during fall 2009. Among its tasks was to consider the question of how large a normal single bed patient room should be. The management and team were well aware of the Expert panel's report and view. Instead of subscribing to the Expert panel's design the project team raised new questions concerning what the design might have excluded or not considered sufficiently well. These questions and issues included values such as the patient's clinical treatment and the staff's work conditions. The budget and efficiency concerns explicated by the Expert panel were not considered irrelevant but rather as one among many relevant concerns that the design needed to take into account.

In order to sort out the design issues and possible implications in a more precise way the project team used a comparative case method. The team did not limit their empirical inquiries to own hospitals but assembled data and empirical material from existing hospital designs in Denmark and abroad (Norway in particular). In this way the team could bench-mark the new and smaller design standard proposed by the Expert panel with a broad range of cases and experiences from hospital designs in use or under construction. The case material showed that the room size for a majority of the hospitals and projects in their study were larger than the expert panel's and closer to 40 square meters. In addition, the case material included a prognosis concerning the size of the future patient's body. The average size of the body was expected to increase quite significantly with further possible design implications concerning the size of the patient room. In the resulting report (Region Hovedstaden 2009) new concerns are raised that were at odds with the Expert panel. For example, the team and region argued that it is necessary to take into account the particular hospital project and design before deciding on a specific room size. However, the report also concluded that the health and safety of the patient might be at risk if the Expert panel's area standard is established as the norm. In terms of the specific design implications the report concludes that the capitol region is opting for a larger room size than the expert panel and is willing to accept higher costs in their hospital construction projects and in operations in order to secure the design for the future patient and body. Like the report from the Expert panel, the report from the capitol region uses cost and budget estimates to qualify their conclusion regarding the design. But unlike the Expert panel, the region uses additional empirical material and experiences from current hospital design and projects as well as extrapolations and scenarios about the future patient and body size.

The project management at Region south was informed about the Expert panel's 33-35 square meters design standard but uncertainties still prevailed. The design would perhaps be economically feasible, but would it also be clinical feasible? In order to sort out the question about the clinical feasibility project management at Region south decided to contract the task to a nearby design laboratory, the Centre for User Driven Innovation. The laboratory consisted of clinical professionals with training in ethnographical methods and action research. The laboratory approached the task by building a full scale physical mock up of a patient room according to the design standard and size set forth by the Expert panel. The room was further equipped with a standard hospital bed and furniture, medical equipment and a living person playing the role as patient. Then there were a number of other persons playing the roles as nurses and doctors. Prior to the simulation all persons in the room were instructed according to a manuscript which included the simulation of a heart attack along with immediate treatment on site. The simulation was filmed and further documented with photographs and feedback from those involved. A report concluded the simulation (Center for brugerdrevet innovation, 2010).

Figure 1: the laboratory simulation. Source : Center for brugerfokuseret Innovation (2010)

Figure 2: the room layout for a possible design based on the simulation results Source: Center for brugerfokuseret Innovation (2010)



The simulation revealed the frictions between bodies and between bodies, equipment and furniture when in motion during the heart attack and treatment. The main conclusion from the report concerns the context of treatment: if the patient or other persons in the room are larger than average, then the Expert panel's design standard might hamper a swift and adequate treatment. This is especially so in acute situations such as heart attack in which medical equipment must be mobilized together with a number of medical professionals. Extra time for these logistics will be required due to the limited space. In contrast to the report from the Capitol region, the report from Region south does not include economic calculations. However, there were instances of economic judgments of a more qualitative nature. For example, the report points out that it might be possible to accommodate concerns for the patient's health and safety within the limited space implied by the Expert panel's design standard. This however, will require further investment in new technological solutions, equipment and furniture in particular such as the 'intelligent bed' and robotics for logistics and waste management. The report does not attempt to estimate the extra economic costs associated with these mitigating investments.

CASE 2: IS THE ROOM BIG ENOUGH? THE UK CASE

This case involves the design of a new specialist hospital in the UK. Currently, the project is in the late stages of tendering, with the announcement of the successful consortium due later in the year. The requirements for the hospital are that all in-patient accommodation has to be single room with en-suite faculties. This is in line with a general shift in opinion within the National Health Service (NHS) in the UK towards the advantages single rooms offer in terms of patient privacy and dignity, control of hospital acquired infection, and access for visitors. But single room only accommodation is unusual in the UK – the first all single room NHS hospital opened in January this year. Various other requirements were specified about natural daylight penetration and visibility of patients from nursing stations, and these presented the design and construction consortia tendering for the project significant challenges in terms of design, but also in communicating to the NHS Trust client that their design fulfilled those requirements.

Our involvement as researchers in this particular case begins with discussions with one of the bidding consortia – 'Consortco' – to explore whether advanced virtual reality technologies could be used to show the client that their design fulfilled, and indeed exceeded the requirements. For the upper floors of the hospital where the in-patient accommodation is located, the design they had developed had an elliptical shape with a central light-well, allowing single rooms to be placed on each side of a corridor and to have external windows (facing either outward or into the light well) extending around the building envelope. This maximized natural daylight, allowed good visibility of several rooms from each nursing station in the corridor, and produced an impressive design. However, this presented some issues. Although not necessarily a firm requirement, the NHS produce various guidelines for hospital design – the Health Building Notes (HBN) and Health Technical Memoranda (HTM). The nature of the design meant that the single rooms were all slightly different (due to the curve in the outer wall) and slightly smaller that the guidelines. So there was a challenge to convince the client that the rooms were big enough, not just for in-patient accommodation, but also for access by crash teams in the case of emergencies.

One way to demonstrate this is through building physical, 1:1 scale mock up (as in the Danish case above) but this is very costly - perhaps £100,000 per model. Physical models are also inflexible - if changes are suggested this would require significant rework. So an exploratory conversation was begun with the University of Reading to see whether the immersive virtual reality facilities within the Visualisation and Interactive Technologies Centre (VIT-C) could be used as an alternative to physical models to establish that the size of the single rooms were adequate. In particular, the CAVE (Cave Automatic Virtual Environment) presented opportunities to show the single room model in an immersive environment, with a 1:1 scale, calibrated to the dimensions of the design model. The CAVE works by simultaneously projecting images of the model onto three walls and the floor or an approximately $4m^2$ space, using active glasses to produce the 3D effect, and head tracking to coordinate the four sets of images. The particular ambitions of Consortco were significant; a decision had been made that the design would be developed in a 3D / BIM environment, so a more-or-less complete model of the hospital had been produced. The initial conversations were therefore to establish how technically difficult (and hence expensive) would it be to take existing BIM models and transfer them into the CAVE, and to see whether they would be of a high enough quality to show the client, be able to demonstrate the scale and configuration of the single room accurately enough to establish that they were big enough, and be user friendly and intuitive enough for a non-construction client to understand and engage with. After establishing that the models could be transferred, a total of seven separate sessions were held in the CAVE, culminating with the visit of seven client representatives to review the models. For the purposes of discussion, we will divide these into two periods; initially establishing viability, and increasing scale and scope of the simulation.

Fig 3: The CAVE showing the en-suite bathroom

Once the technological possibility of displaying the existing models within the CAVE was established, the next step was to check whether the technology, and the simulation, would be a suitable medium for the client demonstration. An initial session was set up where several senior members of the bid team came to the CAVE to assess the single room model. The session exposed a number of interesting issues around the use of the technology, the simulation itself and the design of the room.

As the session began, it became clear very quickly that some time was required for the users to 'orient' themselves to both the CAVE itself (a quite dark space enclosed on three sides) the peripheral artefacts (wearing the stereo glasses, the head tracker and protective footwear) and to the previously un-experienced 1:1 perspective of the model. For instance, proximity to the head tracker (from the position of which the hardware works out how to synchronise the four separate projectors) is needed to keep the correct perspective of the model, and the users quickly worked out that they needed to stand close to the person who was using it, and that it had to be passed around the group to make sure everyone was 'seeing the same thing'. The tension between the scale and size of the simulation - a reasonably large room - and the physical space of the CAVE itself - which is much smaller - became apparent, but this was a different sort of materiality than that seen in the Danish case. At various points, several of the group, fully immersed in the virtual space, walked into the CAVEs projection screens (much to the amusement of the others), forgetting that they were in a smaller space than the virtual room. This was the materiality of the CAVE pushing back onto the 'virtual materiality' of the simulation.

But the users quickly became familiar with both the CAVE itself, and what they were seeing, and the discussions moved onto aspects of the 'fit for purpose-ness' of the simulation. It was agreed that it would be possible, and that the simulation gave a clear indication that the room was indeed 'big enough'. Thus a matter of concern - would it work - was shifted to something else. But this was not, arguably, into a matter of fact, but more into a proliferation of other matters of concern. There were several discussions about how specific aspects might be refined - both in terms of what the 'process' of showing the client the models would be like (free navigation or predefined route? Leave them to it, or provide a 'guided commentary?), and in refining some parts of the model (such as adding more textures to objects, making some objects (such as bed-tables) moveable and so on). The simulation also raised unexpected matters of concern. For instance, on entering the en-suite bathroom of the single room, they were surprised to see so many different fixtures (grab rails etc), many of which seemed to be in the wrong location. This provoked a discussion of why that was - a problem with the perspective of the simulation? An error in the model? A mistake that wasn't picked up through the CAD model on the computer screen or printout? This both made connections between this particular simulation and the design process behind it, as well as to ways to re-design the layout of the bathroom to improve it.

At the close of the meeting, several follow up sessions were planned, to get the modellers and visualisers working on the project to come to see the model, and work out what to do to add the required refinements. Over the course of these sessions, the simulation evolved to incorporate these finer details, but also the scope and scale of the exercise - which was originally just to establish with the client that the room was big enough - escalated significantly. The first request was to expand from a single room to a corridor with four rooms on each side. This would provide a better sense of how the single rooms fit into the overall design, and would establish lines of site from nursing stations - one of the drawbacks of single room only designs. Then it was decided to also produce a simulation of one of the operating theatres complete with all the medical equipment, to show the client the efficiency of the design, and finally to model the main entrance and atrium - very large spaces which were the centre piece of the design. This would allow the client to get a sense of the space, but also to 'walk through' and explore these large open spaces. This represented a significant shift in the role of the simulation - from a tool to address a particular matter of concern - the size of the room - to an integral part of the bid and a way of demonstrating commitment to client engagement, embracement of innovative design technologies and the impressiveness of the design itself. This also showed how the specific matter of concern became re-connected to the rest of the hospital design, through simulating corridors, lines of sight, signage systems in the main areas, and developing a 'virtual tour' and commentary to perform when the client visited. There were other connections established, notably the inclusion of a display of pictures of previous incarnations of the hospital (which began as temporary TB sheds) on the corridor linking the main entrance and atrium, to establish the new design's association with the hospital's legacy.

DISCUSSION

The two cases demonstrate that size matters, but in different ways due to the different material devices of representation and visualization. While both cases use full scale mock ups to simulate the single bed room design, there were also important differences in terms of the material and physical setup. In the UK case the physical setup of the virtual simulation allowed further exploration of links between the room and the building envelope such as the outer curve and the view from nursing stations or reception desks in the atrium. In the Danish case, the physical simulation did not produce further concerns and links between the room and the building envelope. Instead, the concerns remained inside the room's spatial boundary and were taken care of through further refinements of the interior design, for example in the form of more advanced and costly furniture and technological installations. Compared to the Danish case the UK case produce more and closer links to the building envelope and the overall hospital design and concept. The links and boundary of the single bed room can thus be considered to be produced in different ways due to the different methods of design representation and visualization. The boundary appears to be more open and flexible in the UK case.

However, the explanation of this difference can be developed further by considering additional forms of representation and visualization. The Danish case suggests an important role for budgets in making the boundary less open and flexible. Equipped with the program budget the expert panel is prompted to articulate a concern about an economic size for the single bed room. An economic (cost) boundary is drawn for what constitutes a feasible design and room size. This in turn produced a whole array of additional visualizations, representations and clinical concerns among the regions and prospective project and hospital owners. In the physical mock up and simulation these clinical concerns are delimited to focus on the interactions and the treatment taking place inside the economic feasible patient room. In the Danish case it thus appears that the room's eventual links to the building envelope and the overall hospital design becomes relatively more difficult to explore due to this array of interlinked devices and concerns. This circumstance is also one of the emerging concerns expressed by the Capitol region (Region Hovedstaden 2009). But the UK case evolved to be much more concerned with flow and joining up and connecting to what begun as disparate spaces. Throughout these simulations, there was no substantive discussion of cost or budgets. These discussions would, of course, have been taking place elsewhere, but remained separate from establishing and developing the role of these particular simulations.

There are further interesting differencing in the specific materialities of the simulations. For the Danish case the physical simulation produced a concern about friction between bodies and things in motion, that the room placed physical constraints on the ability to perform necessary activities within, it. The UK case had no such physical constraints to the model itself, but the materiality of the CAVE technology did play a part; whether through the necessity of glasses and the head tracker, or through 'forgetting' the physical limitations of the space and bumping into the projection walls.

In terms of the implications for practitioners, the cases reveal two insights. The first is the way that such simulations may be intended to reduce controversy, or establish fact, but in fact can open up new issues, whether as potential problems, or as opportunities to improve the design. The second is that simulations do not exist in isolation; they establish connections to other simulations and concerns, whether other spaces within the hospital, budgets, or policy debates about the size of future patients. Understanding the dynamics of simulation and the way they become enmeshed into other representations and debates, is important to acknowledge.

CONCLUSIONS

Both of these cases are rife with matters of concern; initially over room sizes, but then over suitability of simulations, budgets and political implications, ways to impress clients and so on. Both cases demonstrate how these simulations addressed, but also raised, such matters of concern, and that the simulations were central to holding things together, but also not disconnected from other issues, debates and spaces.

In contrast to the UK, the Danish case pointed to the role and importance of the budget and the 'matter of fact' quality of the economic patient room and size. However the Danish case also suggests that there are costs associated with such premature attempts to reach closure. Other important concerns such as clinical treatment and the room's links to the building envelope and the overall hospital design and concept might be disregarded. In this sense the two cases complement each other by showing that size matters and that it matters in different ways in building design and health care depending upon how the boundaries around a particular design and object are drawn. The material devices for representation and visualization play important and distinct roles in drawing and negotiating the design, its links and more or less open and flexible boundaries. They are central parts of the "on-going accomplishment" of design practices.

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