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ACHIEVING A LEAN WAYFINDING SYSTEM IN COMPLEX HOSPITAL ENVIRONMENTS: DESIGN AND THROUGH-LIFE MANAGEMENT

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ABSTRACT

Complex products, such as buildings and other infrastructure, should aim to provide value to the customer over all stages of the product life-cycle. This paper considers some of the challenges associated with maximising customer value when designing, producing, implementing and maintaining a wayfinding system for complex hospital environments. The hypothesis of this paper is that the tri-partite conception of knowledge flow provides a robust evaluative framework for the problems of wayfinding in complex hospital environments. The framework supplements the concepts of information and practice, conventionally applied in knowledge management, with a conception of physical objects and environments as knowledge carrying entities which are constituted, recognised and used in the course of social practice. From a lean perspective, the problems of wayfinding must be reduced or eliminated through adopting a lean knowledge management approach. A review of knowledge management, design, wayfinding and lean literature, together with ongoing participant action research at Salford Royal hospital, are reported in this paper. To ensure that wayfinding information remains immortal throughout the long life cycles of the building, a Through Life Management (TLM) approach is suggested. Thus TLM is viewed as an important consideration in lean construction.

KEY WORDS

Wayfinding, Design, Tri-partite conception of knowledge flow, Lean knowledge management, Unique adequacy

INTRODUCTION

Complex buildings and other infrastructure aim to provide value to the customer over all stages of the product life-cycle. This paper considers some of the challenges associated with maximising customer value in the case of wayfinding in complex hospital environments. The task of catering for the wayfinding needs of the different groups of users (blind, elderly, children, newcomers, foreign visitors, wheelchair users etc.) who visit hospitals needs careful consideration.

Arthur and Passini (1992) note that wayfinding is a complex concept which has continued to receive the attention of cognitivists, architects, project managers, space planners, interior, graphic, landscape and traffic designers who are keen to influence the way people interact with and perceive their space (Muhlhausen, 2006). Since the concept was first used by Lynch (1960), there has been a vast growth of theories, design principles and methodologies aimed at supporting the design of better wayfinding systems. These have largely been influenced by the thinking that

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wayfinding concerns perception, spatial knowledge, information elaboration, memory and problem solving processes (Muhlhausen, 2006). However, despite all this development, users of complex environments continue to get lost. Thus, it would appear, there remains a need to find a satisfactory solution for dealing with the problems of getting lost in such type of environments.

In this paper it is argued that a lean approach to knowledge management will provide a satisfactory solution to the problems of wayfinding. The authors offer the tri-partite conception of knowledge flow as an appropriate knowledge management solution. In this approach, the concepts of information and practice, conventionally applied in knowledge management, are supplemented with a conception of physical objects and environments as knowledge carrying entities. This approach leads to the hypothesis that wayfinding problems can be effectively evaluated using the tri-partite conception of knowledge flow. This is viewed as a question of managing knowledge flows; the challenge being for designers and producers of wayfinding systems to ensure that the right information in the right form is in the right place at the right time. The authors also highlight the need to ensure that wayfinding information remains immortal throughout the long life cycles (design, built, use/maintain, upgrade and demolish) of the building. A Through Life Management (TLM) approach is suggested as a possible solution to this problem (Koskela et al, 2008). Thus TLM is viewed as an important consideration in lean construction.

The paper offers a brief discussion of the tri-partite conception of knowledge flow and how it might be usefully applied from a lean perspective. A general overview of the concepts of value and waste within the context of wayfinding is given before the focus turns to how customer value can be maximised in the case of Salford Royal hospital. Here specific breakdowns, which are linked to each aspect of the tri-partite conception, are identified and discussed and a possible solutions suggested. A brief discussion of the appropriateness of a TLM approach is offered before the conclusion.

A LEAN KNOWLEDGE MANAGEMENT APPROACH TO WAYFINDING: THE TRI-PARTITE CONCEPTION OF KNOWLEDGE FLOW

A lean approach to knowledge management has been proposed by Rooke et al (2010), based on a tri-partite analysis of knowledge flows. The tri-partite conception of knowledge flow (Rooke et al 2010) complements the current dichotomous approach to the management of knowledge which makes a distinction between knowledge and information (Davenport & Prusak 1998; Quintas 2005; KIM 2006). The conception redefines the informational and practical aspects of knowledge, combining them with a conception of physical objects and environments as information carrying entities which are constituted, recognised and used in the course of social practice. Thus, the formulation includes: [1] information; [2] social practice; [3] the physical properties of objects in which knowledge can be embedded. Rooke et al (2010) highlight the value of the physical (including among others visual and tactile) properties of artefacts in the preservation of knowledge through subsequent stages of the life-cycle of a building and its transfer from artefact to user is emphasised.

Notwithstanding the relative neglect in KM studies of the active role played by artefacts in the transfer of knowledge, communication rendered via physical properties has received attention from a range of other disciplines. In object design, for example, Norman (1998) highlights this key role where he talks about affordances a term which refers to the 'perceived or actual properties' of artefacts 'that determine just how the thing could possibly be used' (1998:9) Similarly, Lawson (1999) argues that spaces communicate with us through their physical properties. In production and

operations management, attention has been given to the rendering of information in visual form and providing transparency to the work situation, especially stimulated by the example of the Toyota Production System (Galsworth 1997; Hines, Francis & Found 2005). The *kanban* system and *Poka yoke* (Shingo 1988) are good examples of this.

THE CHALLENGES ASSOCIATED WITH REDUCING WASTE AND MAXIMISING VALUE IN THE CONTEXT OF WAYFINDING

This paper argues that designers should aim at designing effective wayfinding systems in order to ensure that the right information in the right form is delivered to the right people at the right time. Here, the right information and right form are seen as value issues whilst the right person and right time are viewed as flow issues. For a wayfinding system, right person and right time effectively means having the information at the place where it will be needed by whoever is trying to find their way

The challenges associated with designing for different visitors who come to the hospital with 'different levels of knowing' and 'different needs' (Huelat 2004:4) are immense. These groups include the blind, elderly, children, newcomers, foreign visitors and wheelchair users amongst others. With such a varied range of needs, abilities and knowledge levels, one may be forgiven for questioning the possibility of creating meaningful customer value.

Take for example the well documented wayfinding principle for positioning direction giving signs; *the sign must not be too high or too low the eye level* (DOH, 2005). Whose eye level one may be permitted to ask? Is it that of an average height able-bodied visitor, a child or a wheelchair user? The findings from the empirical study at Salford Royal clearly show that the faithful observation of this principle has resulted in the creation of value for only those who are able-bodied and of average height. In this setting, wheelchair users can be observed struggling to access this crucial information. The tension highlighted above reaffirms the long standing call for the need to give careful consideration to issues of wayfinding.

With this in mind, the authors assert that incorporating the three aspects of the tripartite conception of knowledge flow when designing wayfinding systems will ensure a lean system which should meet the needs of all. Besides, evidence from both literature and current empirical work clearly indicates that in complex environments such as large hospitals, wayfinders tend to rely on the three knowledge flows (Rooke et al, 2009., 2010., Carpman and Grant, 1993., and DOH, 2005). The need to start from the end point of the customer is emphasised by many (Grabau, 2009., Fillingham, 2008) who assert that the first principle of lean is customer value. Arthur and Passini's (1992) assertion that the only way to solve wayfinding issues intelligibly is for designers and architects to

'...pay attention to how people perceive and understand the environment, how they situate themselves in space and how they use information in the decision-making and decision-executing processes' (p.5)

also endorses the first principle of lean (Grabau, 2009). It also points to the need to adopt a suitable methodology when seeking to understand the way people makes sense of complex environments. The value of learning from the behaviour of the end customer is clearly emphasised. A growing keenness by architects and designers to discuss wayfinding needs and solutions with their customers has been noted (Brandon, 2008).

REDUCING WASTE AND MAXIMIZING VALUE AT SALFORD ROYAL HOSPITAL

In this section the empirical work done at Salford Royal hospital is described prior to a detailed discussion of the research methodology. This is followed by a description of how the tri-partite framework was used to deal with the breakdowns encountered during the first phase of the research. An effort is made to show how using the tri-partite approach helped the researcher identify where waste and loss of value occur in the hospital's existing wayfinding system.

THE CASE STUDY: SALFORD ROYAL HOSPITAL

This research was carried out in the large complex hospital environment of Salford Royal National Health Service (NHS) Foundation Trust and is split into two overlapping phases. The first phase studied the existing environment in order to establish how people visiting the hospital make sense of the environment in finding their way. The second phase focuses on informing strategies to improve wayfinding across the hospital. The inadequacy of the wayfinding system at Salford Royal hospital is recognised by management, staff and users alike.

In keeping with the demands of the first principle of lean; specifying value from the standpoint of the end customer (Graban, 2009), a conscious decision was made to follow the Uniquely Adequate requirement of methods (Rooke and Kagioglou, 2007). Doubts as to the extent to which surveys and semi-structured interviews can capture detail in a manner that an eye witness experience can influenced this decision. The authors are convinced that following this criteria allowed for the identification of subtle but important details which may have been overlooked by surveys and interviews. Research informed by the Unique Adequacy (UA) criteria is well known in Computer Supported Cooperative Work (see, for instance: Crabtree 2004). This research has mainly been concerned with reporting to designers on the activities of customers, or prospective customers. Work has also been done to develop UA approaches which make a more active contribution to the design process (Button & Sharrock 1995; Button & Dourish 1996; Dourish & Button 1998) or encourage reflection in design and management processes (Rooke & Seymour 2005).

THE UNIQUE ADEQUACY REQUIREMENT OF METHODS

Unique Adequacy comes from the discipline of Ethnomethodology. The latter is a sociological approach distinct from traditional sociological approaches in that it concerns itself solely with how observable social activities are produced, accomplished and understood by ordinary members of society (Francis and Hester, 2004). The UA requirement of methods consists of two criteria: the weak and strong forms (Francis and Hester, 2004). In its weak form, it demands that to analyse a setting adequately, one must know what any participant in that setting would ordinarily know about it. This knowledge, expressed as competence, is the kind referred to by Ryle (1963) as 'knowing how'. The question of whether such an understanding has been achieved is open for the judgement of any other competent participant, observe Rooke et al (2009). In this form, the requirement meets the criteria for adequate ethnography (Garfinkel & Wieder, 1992), the most appropriate method for acquiring such knowledge being participant observation.

By contrast, the strong requirement concerns the reporting of research. It demands that the methods of analysis used to report on a setting should be derived from that setting (Rooke and Kagioglou, 2007). In effect, it stipulates the application of a policy

of 'ethnomethodological indifference': a refusal to evaluate, describe or explain the activities that constitute the setting using criteria, concepts or theories that are not a part of that setting (Rooke et al, 2009). This criterion is possible because organizational settings are constituted using methodological procedures that are sufficient to account for them. Thus, producing a description of that setting is a matter of seeing how that setting is made to work by its members and presenting these methods in the report. Any other methods must involve some distortion of the phenomenon.

The research at Salford Royal conformed to the UA requirement of methods. The principal method of research was for the researcher to reflect upon and report her own attempts to navigate the hospital site. Data, in the form of photographs, remembered conversations and personal experiences, was initially collected in ten separate visits spread over a period of two months. The objective of each visit was to physically find at the hospital site a specific department (e.g. dermatology, radiology, maternity, outpatients department etc.) chosen at random and previously unknown to the researcher. In undertaking these journeys, the researcher was a visitor to the hospital who was unfamiliar with the hospital lay-out. As such, she was in the same position as any other visitor to the setting, whether patient, visitor, or new staff member.

This approach clearly has its limitations because with each visit familiarity with the site layout increases and the researcher's natural sensitivity to wayfinding problems is consequently diminished. However, these initial experiences have proved a rich source of data. In addition, the researcher observed how people made sense of the hospital environment and photographed artefacts which aided, or were designed to aid wayfinding. These direct observations were supplemented by conversations with other visitors to the hospital and with members of staff and hospital voluntary workers. No formal interviews were conducted, but a wide range of discussions arose spontaneously in the research setting with staff (nurses, porters, Patient Advice and Liaison Services (PALS) personnel, Women's Royal Voluntary Services (WRVS) volunteers) and other users of the setting (visitors and patients).

USING THE TRI-PARTITE CONCEPTION OF KNOWLEDGE FLOW TO CLASSIFY THE WASTE IDENTIFIED IN THE WAYFINDING SYSTEM.

Following the initial analysis of the data which conformed to the UA criteria, a report identifying both helpful and unhelpful aspects of the environment as seen by the users of the setting was produced. Using the tri-partite framework made the job of classifying the breakdowns encountered in this setting manageable. It also made it possible for the researcher to concentrate on articulating the nature of the breakdowns, where exactly in the wayfinding system they occur and how such breakdowns lead to getting lost. Some of these are briefly described below.

Information

Coded information is evident in the large volume of signs which can be seen along the walls, above doors and hanging from the ceiling. However, the heavy volume of signs appears to create more confusion in the wayfinder for two observable reasons: 1) the layout of the hospital is far too complex to explain with signs, 2) the large amount of signs intended to help the wayfinder creates what Passini (1984) refers to as information overload. Muhlhausen (2006) points out that whilst signage plays an important role in wayfinding, on its own it is not enough to address the problems encountered when navigating unfamiliar environments. This argument is endorsed by

several others, for example, Baskaya et al (2004), Haq & Zimring (2003) and Huelat (2004). Others assert that well-designed signs are likely to be quite ineffective in a building that is highly complicated and does not provide simple cues that enable natural movement (Ruddle and Peruch, 2004). Quite often people feel stupid for lacking the acumen to navigate complex buildings leading to loss of value. Thankfully, as many who have studied wayfinding will assert, getting lost is an indication of either a poorly designed environment or wayfinding system and not inadequacy on the part of the wayfinder (Arthur and Passini., 1992; Baskaya et al., 2004; ; Butler et al., 1993; Haq & Zimring, 2003; Huelat., 2004).

Practice

It is hospital policy that its staff must offer help to anyone lost or appearing to be lost. In extreme cases, the staff must take those lost all the way to their destination. This practice can be observed in the behaviour of both the instruction giver and the wayfinder. Anyone who stops long enough may come to the conclusion that volunteers and members of staff at this hospital are giving directions all the time. Some staff admit to finding themselves dividing their working day between direction giving and their normal duties. Evidence that the system heavily relies on it staff and volunteer is also reflected in the chaos that occurs during the days and times when volunteers and personnel are off duty. A good example is that of the disruption of a Saturday outpatient clinic where nurses running the clinics battle to meet the demands of their paid job and those of giving directions to visitors.

Practices such as giving directions are more expensive than physically embodied information. The impact of getting lost on both the physical health of the wayfinder and fiscal health of an organisation is well documented. Huelat (2004) likens good wayfinding with good patient flow, and asserts that applying simple organizational, architectural and graphic principles not only reduces patient stress and anxiety, but can lead to improved health. Zimring (1990) found that the hidden costs associated with direction-giving by people other than information staff equalled the cost of employing two full time professional. Needless to point out that the lost hours could be better spent delivering better healthcare services to the patients.

Physical properties

The impact of the physical properties of hospital on wayfinding is generally overlooked. Apart from the widespread use of colour coded features of the built environment such as skirting boards, strips on the wall etc. to aid wayfinding there appears to be little awareness of the invaluable role of the physical properties. Unfortunately even the use of colour has caused more confusion in that the same colour used to aid wayfinding in one part of the hospital is used decoratively in another. The decoration is done in such a way that creates the impression that it is a wayfinding aid. Those who solely depend colour to find their way often express their frustration at the ambiguity created by this oversight. Clearly, information without the correct physical form and context can be ambiguous or misleading. This may in turn lead to loss of customer value. The waste occurs where the flow of information through physical properties has broken down. This requires re-work (Ohno, 1988) in the form of verbal instructions from staff and volunteers as has been highlighted above.

Using the tri-partite framework to classify the breakdowns at Salford Royal has made an impact on three levels. First, the resultant report was positively received as were the preliminary recommendations made and the continued involvement of the

researcher in the process of designing a better wayfinding system was encouraged. Second, it has made the researcher aware of the framework's utility not only as an evaluative tool but one that can be used to sensitise designers to the varied needs and knowledge levels of wayfinders (Huelat, 2004) when designing systems in the first instance. Third, the process has made it possible to follow the emergence of generic patterns upon which guidelines can be developed. Based on these, strategies for improvement are currently being suggested and implemented. In the next section of one of these is discussed.

PROPOSING STRATEGIES FOR IMPROVEMENT ON THE BASIS OF THE TRI-PARTITE CONCEPTION AND THROUGH-LIFE MANAGEMENT

Through action research, recommendations for improvement continue to be successfully implemented. For example, the immediate removal of the upward pointing arrow placed above a cupboard appears to have reduced the waste occurring at this decision making point (Rooke et al 2010). The sign was read by wayfinders as meaning straight ahead through the door, a reading that relies upon the understanding that, a sign above a door indicates that the destination written on the sign is to be reached through that door. Clearly the physical placement of the information bearing signs, is critical to their interpretation. Inappropriate placement so affects the context in which the information is perceived as to render it ambiguous, leading to a breakdown of the knowledge flow. Specific breakdowns occurring on the most confusing route continue to be analysed and solutions are being developed. The solutions are being tested by observing the response of the wayfinder in context and in discussions with the hospital's redevelopment team.

Evidence from both literature and current fieldwork suggests that wayfinding is rarely incorporated into the design process from an early stage and that quite often it becomes an unsatisfactory afterthought rather than an integral part of the entire process (Arthur and Passini, 1992). Koskela et al (2008) note that the job of managing complex built facilities to continually perform effectively and efficiently throughout long life cycles is a challenging one. They suggest a list of some possible challenges: changing nature of end-user needs, financing arrangements, policies and business needs. The challenge is to ensure that wayfinding information remains alive throughout the various stages of the life cycle of a building.

At Salford Royal, it is clear that following refurbishment or part demolition the wayfinding system has not been upgraded accordingly thus resulting in the death of vital wayfinding information over the course of time. The authors are convinced that the solution to such problems lies in the discipline of Through-life Management (TLM). TLM refers to the management of complex buildings such as hospital through-Life (Koskela et al, 2008). It is, therefore, an important consideration in lean construction. While TLM has been widely practised in the aerospace industry (Oliva and Kallenberg, 2003) it is less prominent in the built environment (Koskela et al, 2008). Future discussions will argue that a lean TLM of a wayfinding system is possible and that it can be realised though the involvement of key stakeholders .

CONCLUSIONS

This paper hypothesised that the tri-partite conception of knowledge flow is a robust framework for evaluating the problems of wayfinding in complex hospital environments. This hypothesis was tested in the complex environment of Salford Royal hospital where the inadequacy of the wayfinding system is recognised by

management, staff and users alike. Testing the hypothesis on data collected and analysed using the UA requirement of methods has led to three conclusions. First, that using the tri-partite framework to classify the problems of wayfinding allows for a robust identification of the true nature of the problems and where they occur in the wayfinding system. Second, that the framework can be effectively used to sensitise designers to the varied needs and knowledge levels of wayfinders when designing systems in the first instance. Third, that the process makes it possible to follow the emergence of generic patterns upon which guidelines can be developed. In addition the paper has highlighted the need to ensure that wayfinding information remains immortal throughout the long life cycle (design, built, use/maintain, upgrade and demolish) that complex environments remain in use. A Through Life Management (TLM) approach has been suggested as a possible solution to this problem. It is proposed that future work should consider a the possibility of a lean TLM of a wayfinding system.

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REFERENCES

- Arthur, R. & Passini, R. (1992) *Wayfinding: People, signs and architecture*, McGraw-Hill, New York.
- Baskaya, A., Wilson, C. & Ozcan, Y. (2004) Wayfinding in a unfamiliar environment. Different spatial settings of two polyclinics. *Environment and Behavior*, 36(6), 839-867.
- Brandon, K. (2008). Wayfinding, <http://www.kellybrandondesign.com>
- Butler, D., Acquino, A. L., Hissong, A. A., & Scott, P. A. (1993). Wayfinding by newcomers in a complex building. *Human Factors*, 25(1), 159-173.
- Button, G. and Dourish, P. (1996) 'Technomethodology: Paradoxes and Possibilities,' in A. Miller (ed.) *Proceedings of the ACM Conference on Human Factors in Computing Systems CHI'96*, Vancouver, BC, 19-26 April. New York: ACM. <http://www.ics.uci.edu/%7Ejpd/publications/1996/chi96-technomethodology.pdf>
- Button, G. & Sharrock, W. W. (1995) 'The Mundane Work of Writing Computer Code' in G. Psathas & P. ten Have, eds., *Situated Action*, University Press of America.
- Carpman, J., & Grant, M. (1993). *Design that cares: Planning health facilities for patients and visitors* (2nd ed.). Chicago: American Hospital Publishing.
- Carpman, J., and Grant, M. (2001). *Design that cares*. San Francisco: Jossey-Bass Inc.
- Crabtree, A. (2004) "Finding out what users want" - articulation and translation at the library help desk,' in *Proceedings of the 6th International Conference on Ubiquitous Computing*, September 7th Nottingham, Springer, Berlin.
- Davenport, T. H. & Prusak, L. (1998) *Working knowledge; how organizations manage what they know*, Harvard Business School Press, Boston, MA.
- Department of Health (2005) *Wayfinding: Effective Wayfinding and signage systems, guidance for healthcare facilities. DOH HMSO*
- Dourish, P. & Button, G. (1998) 'On "Technomethodology": Foundational Relationships between Ethnomethodology and System Design', in *Human-Computer Interaction*, 13(4):395-432.

- Fillingham, D (2008). *Lean Healthcare: Improvingnt's experience*, Kingsham Press, Chichester
- Francis, D. and Hester, S. (2004) *An Invitation to Ethnomethodology; Language, Society and Interaction*, Sage, London.
- Galsworth, G. D. (1997) *Visual Systems:Harnessing the Power of a Visual Workplace*, American Management Association, New York
- Garfinkel, H. and Wieder, D. L. (1992) 'Two Incommensurable, Asymmetrically Alternate Technologies of Social Analysis', in G. Watson & R. M. Seiler (eds.), *Text in Context*, Sage, London, pp. 175-206.
- Graban, M (2009). *Lean Hospitals: Improving quality, patient safety and employee satisfaction*, Productivity Press, Taylor and Francis Group New York
- Haq, S., & Zimring, C. (2003). Just down the road a piece: The development of topological knowledge of building layouts. *Environment & Behaviour*, 35(1), 132-160.
- Hines, P., Francis, M. & Found, P. (2005) 'Lean LifecycleLife cycle Management,' *CUIMRC Working Paper Series*, University of Cardiff.
- Huelat, B. J (2004), *The Elements of a Caring Environment - Wayfinding. Healthcare Design Magazine Cleveland, OH: Medquest Communications*, September
- KIM (2006) *Knowledge and Information Management (KIM) Grand Challenge Project* www.ukoln.ac.uk/projects/grand-challenge/
- Koskela, L. (2000). *An exploration towards a production theory and its application to construction*, VTT Technical Research Centre of Finland, VTT Publication 408.
- Koskela, L.J., Siriwadana, M., Rooke, J.A., (2008) *Through-life Management of built facilities: Towards a framework for analysis*. In *IGLC 16 Proceedings*, 16-18 July, Manchester, UK, pp. 61-71
- Lawson, B. (1999) *The Language of Space*, Architectural Press, Oxford.
- Lynch, K. (1960) *The image of the city*. Cambridge, MA: MIT Press
- Muhlhausen (2006) *Wayfinding Is Not Signage* <http://www.signweb.com>
- Norman, D. A. (1998) *The design of everyday things*, Basic Books, New York
- Oliva, R. & Kallenberg, R. (2003) 'Managing the transition from products to services', *International Journal of Service Industry Management* 14(2):160-172.
- Passini, R. E., (1984) *Wayfinding in Architecture*, Van Nostrand Reinhold, New York.
- Quintas, P. (2005) 'The Nature and Dimensions of Knowledge Management' in C. Anumba, C. Egbu & P. Carillo (Eds.) *Knowledge Management in Construction*, Blackwell, Oxford.
- Rooke, J. & Kagioglou, M. (2007) 'Criteria for evaluating research: the unique adequacy requirement of methods,' *Construction Management and Economics*, 25(9):979-987.
- Rooke, J. & Seymour, D. (2005) 'Studies of Work: Achieving Hybrid Disciplines in IT Design and Management Studies', *Human Studies* 28(2):205-221
- Rooke, C.N., Rooke, J.A., Koskela, L.A., Tzortzopoulos, P.(2010) 'Using the physical properties of artefacts to manage through-life knowledge flows in the built environment, an initial exploration', *Construction Management and Economics. Special Issue on Objects, Knowledge sharing and Knowledge Transformation in Projects* (In Press)
- Rooke, C.N., Tzortzopoulos, P., Koskela, L.J. and Rooke, J.A. (2009) *Wayfinding: Embedding knowledge in Hospital environments*. In: *HaCIRIC Conference*, 2-3 April, Brighton, UK, pp. 158-167.

- Rooke, J.A., Koskela, L.J., Kagioglou, M. (2009) Informality in organization and research: a review and proposal, *Construction Management and Economics*, **27**:913-922
- Ruddle R. A., & Peruch P. (2004). Effects of proprioceptive feed
- Ryle, G. (1963) *The Concept of Mind*, Penguin, Harmondsworth.
- Shingo, S. (1988) *Non-stock production :the Shingo system for continuous improvement*, Productivity Press, Cambridge Mass.
- Zimring, C, (1990). *The Cost of Confusion: Non-monetary and monetary cost of the Emory University hospital wayfinding system*. Atlanta: Georgia Institute of Technology