INTERDISCIPLINARY INTERACTION DURING CONCEPT DESIGN

John Steele[2], Simon Austin[1], Sebastian Macmillan[2], Paul Kirby[2], Robin Spence[2]

[1]*Department of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK*
[2]*The Martin Centre for Architectural and Urban Studies, Department of Architecture, University of Cambridge, 6 Chaucer Road, Cambridge, CB2 2EB, UK*

Decisions taken during the conceptual design phase of a project have fundamental and extensive effects on both cost and performance. There are growing demands on interdisciplinary design teams to generate better and more innovative solutions to problems of increasing complexity. To meet these demands, more efficient and effective design methods and processes are required. At present, there are no construction industry guidelines to assist focused interdisciplinary team interaction during the conceptual phase of design.

This paper will describe current research work to study the conceptual design activity of interdisciplinary teams. It will describe two recent design workshops that were held to allow real-time design activity to be monitored and mapped, and a preliminary conceptual design framework to be tested. The findings of the workshop highlight the iterative nature of conceptual design activity and provide much needed insights into the ways in which interdisciplinary teams progress during the early phases of design.

Keywords: conceptual phase, design process, interdisciplinary, teamwork.

INTRODUCTION

The introduction of the interdisciplinary design team is a relatively recent phenomenon, emanating from the scope and complexity of many tasks and the need for multiple expertise and labour division (Goldschmidt 1996). The forming of the design team is a means of weaving the individual qualities of each specialist designer back into a single 'extended brain'. That being a brain that contains as much information, knowledge, experience and thinking power as possible. However, once a number of people are involved in any activity it introduces another dimension to the situation: team member interaction.

OPPORTUNISM VERSUS SYNCHRONIZATION

The majority of work in the conceptual phase of building projects is undertaken in an unplanned and *ad hoc* manner. This opportunistic behaviour, which occurs when the designer pursues ideas as and when they occur, may be appropriate for the individual designer, but not for interdisciplinary design teams, as interaction and collaboration need to be co-ordinated to maintain team effectiveness (Goldschmidt 1996). If the design activity is left uncoordinated, an opportunistic deviation initiated by one team member

[1] S.A.Austin@lboro.ac.uk
[2]sgm24@cam.ac.uk

Steele, J, Austin, S A, Macmillan, S, Kirby, P and Spence, R (1999) Interdisciplinary interaction during concept design. *In:* Hughes, W (Ed.), *15th Annual ARCOM Conference*, 15-17 September 1999, Liverpool John Moores University. Association of Researchers in Construction Management, Vol. 1, 297-305.

may be seen as irrelevant and inappropriate by another (Cross and Clayburn-Cross 1996). This, or in fact any, lack of synchronization in focusing on a collaborative goal can cause serious problems for team members in interactions and communications and lead to misunderstandings and uncoordinated actions (Valkenburg and Dorst 1998). However, evidence suggests that even in cases where problems are handled intuitively or opportunistically, the designer is better able to ruminate on a particular problem when in possession of a general programme of events through which the activity is likely to pass (Archer 1984). It has been shown that effective interdisciplinary design activity relies on all of the team members supporting each other and the interaction of every member of the project team. Design solutions emerge not only from flashes of inspiration by individual team members, but also through interactions and negotiations among team members.

The few researchers that have studied group design have concentrated their studies on the field of engineering design. However, there is a general agreement among these individuals that shared understanding between design team members can aid the decision-making process and is the key to successful collaboration. There is no doubting that it is difficult to achieve effective operation of a large interdisciplinary design team (Bessant and Macmahon 1979). However, a way of improving this has been found to be the implementation of a design methodology, because it more or less imposes group dynamic effects and interdisciplinary co-operation (Pahl 1991, Blessing 1994). It is these conjectures, among others, that the MDP (Mapping the design process during the conceptual phase of building projects) research project, currently being undertaken at the University of Cambridge, aims to test. It is also intended that evidence will be gathered to improve understanding of how interdisciplinary design teams actually progress through the process of conceptual design.

WORKSHOPS TO MAP INTERDISCIPLINARY DESIGN

Introduction to workshops

This paper compares the ways that several teams undertook the conceptual design of a window system in two ‘Designing Together’ Workshops, each involving 15 design professionals. The first involved designers from AMEC Construction Ltd, a single multi-disciplinary organization collaborating in the research; the second involved designers from each of the MDP project’s industrial collaborators (including AMEC). These experimental sessions were held to map interdisciplinary team working using a preliminary conceptual design framework developed during the initial 12-months of the research project (Figure 1).

General workshop format

The format of the two-day workshop was derived from that used in the University of Cambridge Interdisciplinary Design in the Built Environment course. An experienced facilitator with a background in construction led the sessions. Initially on day one the teams were asked to introduce themselves and carry out a preliminary exercise for the design of a newspaper, which was aimed at encouraging team member interaction in readiness for the main exercise. The main exercise involved the design of a window façade system for the re-cladding of 1960s office buildings. Upon completion of the exercise on day two, the teams were given 30-minutes to present their concept proposals and describe the design processes followed. A panel of three independent experts then critiqued the proposals with respect to the ease with which they could be subsequently developed into workable solutions that satisfy the brief.

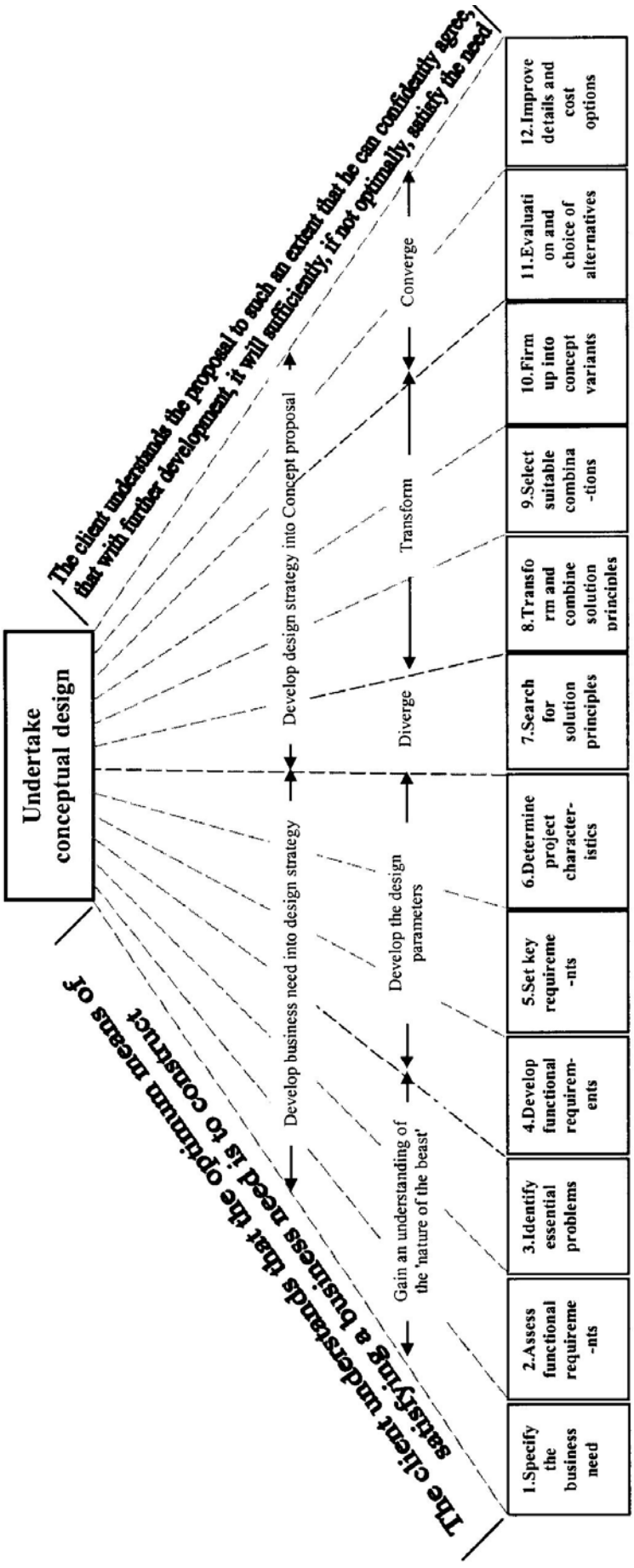

Figure 1: The preliminary conceptual design framework model

Workshop 1: Teams from a single organization

Three teams of five designers, all from the AMEC organization, were asked to undertake the exercise without being given any form of pre-structured design process to follow. Members of the MDP research team monitored the design activity of the teams throughout the session, making detailed notes of both activities undertaken and team member interactions. During the final presentation each team was asked to describe the design process that they followed during the course of the exercise.

The details gathered during the course of this session, when combined with findings made during the literature survey and interviews with professional designers, permitted the development of the preliminary 12-phase framework (shown in Figure 1). This framework benefits from, and is compatible in its terminology with maps from several other industries (Macmillan *et al.* 1999a) and the few existing building design and construction models e.g. Salford Process protocol (1998) and BAA project process (1995). Once generated, the framework was used to analyse the monitored data gathered during the workshop. This then allowed the generation, and subsequent comparison, of the patterns of actual design progression for each of the teams. Austin *et al.* (1999) provide a detailed account of this workshop and its findings.

Workshop 2: Teams from several organizations
This workshop also involved three teams of five designers. However, the teams comprised individuals form a number of organizations. Two teams were given the 12-phase framework, with one team being given the option to follow it and the other asked to follow it. They were then tutored on its terminology and structure. The third team was asked to solve the design problem without being introduced to the framework (as in workshop 1). The session was monitored by the MDP researchers, but in addition each team was asked to record their design activities at five-minute intervals throughout the course of the exercise. Two questionnaires, regarding the design framework and team performance respectively, were utilized to elicit further information from the members of each team. The reader is referred to Macmillan *et al.* (1999b) for details of this workshop and the conclusions drawn regarding both the processes followed and the questionnaire responses. The data recorded during this session allowed each team's individual pattern of design progression to be produced.

WORKSHOP RESULTS AND COMPARISONS

Patterns of design progression
The design progression of each team is shown in Figure 2. The vertical axis represents the sequence of phases outlined by the framework, and the horizontal axis represents time spent over the duration of the exercise. The additional row at the bottom of each figure represents the point in the process, and the time spent, undertaking activities which could not be classified within the phases of the preliminary framework.

It is noticeable that three of the four teams without a framework to utilize (A_1, B_1 and C_2) progressed by taking a number of iterative steps. This is particularly noticeable in team A_1's progression, with two iterations being undertaken to establish requirements, followed by a second two to develop the proposal. Team B_1 iterated twice to develop the proposal, once the requirements had been initially established, whereas team C_2 progressed through all phases very quickly, before undertaking a second loop from phase 5 onward. Team C_1 is the anomaly to this pattern. However, this may owe much to the fact that team C_1's members spent a long period of time, approximately 35

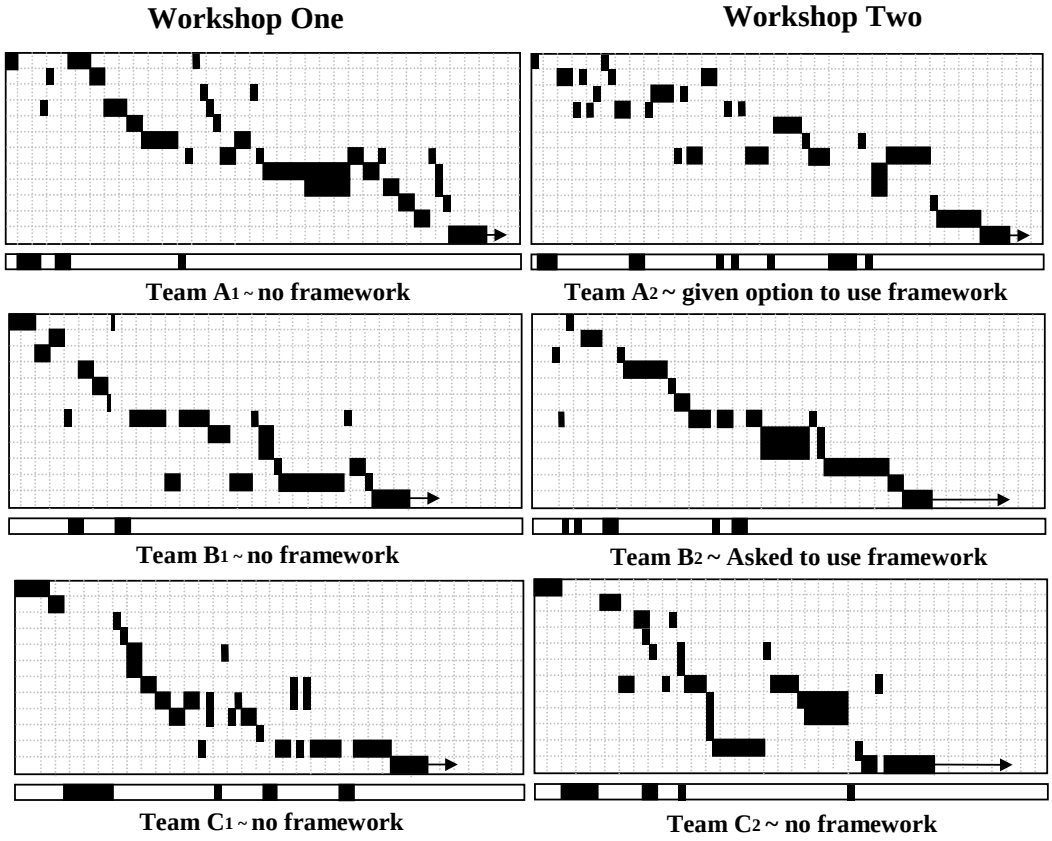

Figure 2: Patterns of design progression for each team in each workshop

minutes, near the outset of the exercise discussing, and subsequently generating, a design procedure to follow.

These iterative bursts are conspicuous by their absence in the design progression of the teams that were provided with the conceptual design framework i.e. teams A_2 and B_2. However, there is noticeable difference in the fashion in which these two teams progressed. This difference can be accounted for by the ways the team's used the framework.

Team A_2 used it as a guide to the design phases which needed to be undertaken over the course of the exercise and not as a systematic procedure. As such, although the team jumped between the phases of the framework opportunistically, there was still linearity within the pattern of progression, albeit fairly loose, without the iterative loops portrayed by the teams without the framework.

Conversely team B_2, after some initial hesitancy, followed the phases of the framework sequentially in an almost linear fashion without iteration being performed.

An additional observation concerned the nature of the final proposals generated by teams C_1 and A_2, which both produced 'Kit-of-parts' proposals. This is in contrast to the proposals generated by the other teams, which were integrated solutions. This is interesting owing to the fact that teams C_1 and A_2 were the only two teams of the six monitored where there was noticeable adversarial and confrontational atmosphere

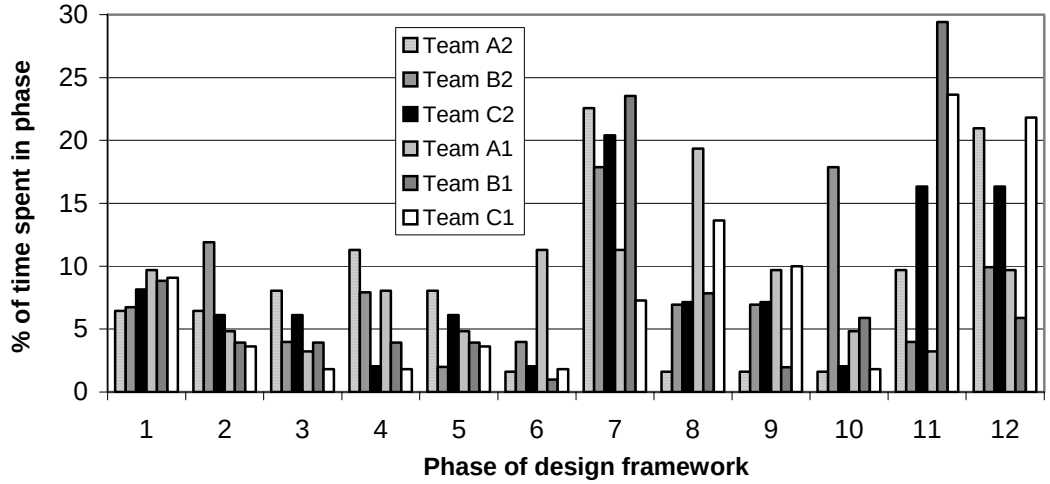

Figure 3: Comparison of time spent in respective phases of design by teams

Table 1: A comparison of time spent in the respective phases of design

			% of time spent in design phase					
			Workshop 1			Workshop 2		
		Phase name	A_1	B_1	C_1	C_2	B_2	A_2
Developing need into a design strategy	1	Specify the need	9.7	8.8	9.1	8.2	6.7	6.5
	2	Assess functional requirements	4.8	3.9	3.6	6.1	11.9	6.5
	3	Identify essential problems	3.2	3.9	1.8	6.1	4.0	8.1
	4	Develop functional requirements	8.1	3.9	1.8	2.0	7.9	11.3
	5	Set key requirements	4.8	3.9	3.6	6.1	2.0	8.1
	6	Determine project characteristics	11.3	1.0	1.8	2.0	4.0	1.6
Developing design strategy into concept proposal	7	Search for solution principles	11.3	23.5	7.3	20.4	17.9	22.6
	8 9	Transform and combine solution principles Select suitable combinations	29.0	9.8	23.6	14.3	13.9	3.2
	10	Firm up into concept variants	4.8	5.9	1.8	2.0	17.9	1.6
	11	Evaluation and choice of alternatives	3.2	29.4	23.6	16.3	4.0	9.7
	12	Improve details	Not included in comparison					
Time unclassified by phases of model			9.8	6.0	22.0	16.5	9.8	20.8
Total spent in phases 1-6			41.9	25.4	21.7	30.5	36.5	42.1
Total spent in phases 7-12			48.3	68.6	56.3	53.0	53.7	37.1

Table 2: Comparison of unclassifiable activities between workshops

	Teams in workshop 1			Teams in workshop 2		
Actvities undertaken which were unclassifiable within the existing phases of the framework	A_1	B_1	C_1	A_2	B_2	C_2
Planning and generating a design process to follow	✓		✓			✓
Allocation of elements of design for each team member to undertake	✓	✓	✓	✓	✓	✓
Allocation of time periods for producing deliverables	✓	✓	✓	✓	✓	✓
Discussions held in a bid to maintain performance or redirect the team			✓	✓		
Introductions and outlining of roles by team members				✓	✓	✓
Pooling of team knowledge in a briefing period	✓			✓	✓	
Connectedness of elements of both problem and solution made explicit						✓

between certain members. In this sense, this finding suggests that there is a clear link between the social interaction of the team and the product generated.

Design phases

Table 1 provides a breakdown of the percentage of time spent by the teams in each of the phases of the framework. A graphical representation of Table 1 is provided in Figure 3.

Initially the data suggests that there is a link between the amount of time that was unclassifiable and the teams in which confrontational attitudes were apparent , but this is not the case. As has been stated previously, team C_1 spent the majority of this time discussing and defining their design process, whereas team A_2 used the time to introduce and understand one anothers team and professional roles initially.

However, the remainder of this unclassifiable time was spent in a similar manner by both teams, in discussions attempting to resolve disputes and implement some form of team maintenance. The differences and commonalities between the teams over both workshops are identified in Table 2.

Disregarding the previously unclassified activities of teams C_1 and A_2, which were the result of attempts to maintain the team, it was noticeable that in general the teams involved in workshop 1 spent part of their non-design time in a different manner to the teams in workshop 2. Table 2 makes a comparison between the two workshops in terms of these unclassified activities that averaged 14% of the time (See Figure 4).

All teams planned their activity in terms of allocation of resources and time, irrespective of being provided with the framework or not. It is apparent that, of those teams not given the framework, only team B_1 did not attempt to agree a design process. This is the result of the team's decision to progress in an *ad hoc* fashion, owing to their performance during the preliminary exercise. The reasoning behind this decision was given as; "If it's not broken why fix it?"

Teams C_1 and A_2 were the only teams that needed to address explicitly the social interaction aspects of the team (team maintenance). This owed much to the fact that there was a confrontational atmosphere apparent between members in these teams, whereas in general the other teams negotiated common understanding and agreed on direction to progress.

Unclassifiable activity across workshops

All teams in workshop 2 (but none in workshop 1) undertook an introduction of team members and the outlining of their team roles. This would suggest that this procedure is a necessity for newly formed teams. Owing to the fact that the delegates of workshop 1 knew one another professionally, as well as socially in the majority of cases, this phase was not necessary.

The pooling of team knowledge was undertaken by some teams and not by others. This appeared to be undertaken only when one team member suggested it to his / her counterparts. Finally, the identification of the connectedness of certain aspects of the design was only undertaken explicitly by team C_2. This is not to suggest that the other teams did not attempt to do this as it may have been undertaken by each designer before forwarding concepts. However, the panel of judges stated that only the proposal of team C_2 reflected that this activity had been undertaken.

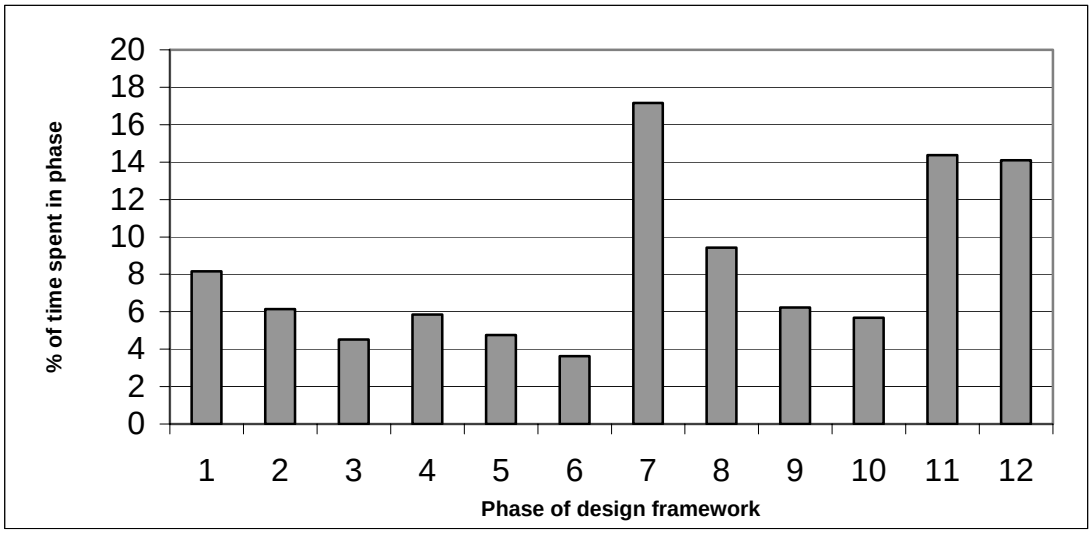

Figure 4: Average time spent in phases of design (average of all teams)

Time spent in design phases

Figure 4 depicts the average time spent in each phase of the framework by all teams monitored during the two workshops.

Disregarding unclassified activities, it can be seen that, in terms of time spent within each phase, the most prominent are 7 (Generation - 17%) and 11 (Evaluation - 14%), followed by phase 8 (Transformation - 9%), which in total account for approximately 40% of design time. As such, it is apparent that the interdisciplinary teams in the two workshops spent up to 60% of their design time undertaking activities other than generating, transforming and evaluating concepts.

CONCLUSIONS

- Each of the teams undertook the same design phases over the course of the exercise. However, the sequence and duration of the phases varied greatly between teams.
- The two teams that were provided with the design framework progressed fairly linearly without obvious iteration. This is apparent despite of the fact that one team followed it stringently while the other used it purely as a guiding principle.
- Conversely, those teams that were not provided with the design framework tended to progress in a number of iterative bursts. These iterations occurred irrespective of whether the teams had pre-defined a design process for themselves or not. However…
- When teams agreed a process in advance it appeared to help the members to adhere to a programme and work in accordance with it.
- Paradoxically, in these workshops, the use of a pre-defined design process, be it self generated or provided, did not lead to better design proposals, nor reduce the time taken to complete the project.
- The teams in which members worked well together produced integrated solutions. The two teams in which conflict was apparent between members, produced kit-of-

parts design solutions. In this sense there was a clear link between the process and the product.

- The teams of individuals from the single organization began the exercise less formally and were more relaxed with one another on a social level, whereas the multi-organizational teams commenced formally and attempted to decrease formality with initial introductions. These differences did not stop confrontation in either workshop.
- The design framework developed to describe the sub-phases of the conceptual phase was supported by the findings of the workshops, but it fails to account for a major factor of successful design team working, namely self-management / maintenance by the design team.

ACKNOWLEDGEMENTS

The industrial collaborators in this project are: AMEC Design; BAA, Hotchkiss Ductwork Ltd; Hutter, Jennings and Titchmarsh; Matthew Hall; and Pascall and Watson. Loughborough University is also contributing to the project.

REFERENCES

Archer, B.L. (1984). Systematic method for designers. *In:* Cross, N (ed) *Developments in design methodology.* Chichester: Wiley.

Austin, S., Steele, J., Macmillan, S., Kirby, P. and Spence, R. (1999) Using training workshops to map interdisciplinary team working. In: *Procs CIBSE National Conference '99,* Harrogate, UK, 3-5 October.

Bessant, J R and Macmahon B J (1979) Participant observation of a major design decision in industry. *Design Studies*. **1**(1), 21–26.

Blessing, L.T.M (1994) *A process-based approach to computer-supported engineering design.* PhD Thesis, Department of Mechanical Engineering, University of Twente, The Netherlands.

British Airports Authority (1995). The Project Process. London: BAA.

Cooper, R., Kagioglou, M., Aouad, G., Hinks, J., Sexton, M. and Sheath, D.M. (1998) Development of a generic guide to the Design and Construction Process. *In: Procs Eur. Conference on Product Data Technology*. Watford: Building Research Establishment, 205–214.

Cross, N. and Clayburn-Cross, A. (1996) Observations of teamwork and social processes in design. *In:* Cross N, Christiaans H and Dorst K (eds) *Analysing design activity*. Chichester: Wiley, 291–317.

Goldschmidt, G. (1996). The designer as a team of one. *In:* Cross, N., Christiaans, H. and Dorst, K. (eds) *Analysing design activity*. Chichester: Wiley, 65–91.

Macmillan, S., Steele, J., Austin, S., Spence, R. and Kirby, P. (1999a) Mapping the early stages of the design process: a comparison between engineering and construction. *Procs 12th International Conference on Engineering Design (ICED '99).* Munich, Germany (in press).

Macmillan, S., Steele, J., Austin, S., Spence, R. and Kirby, P. (1999b) Observing interdisciplinary working in a designing together workshop. Internal paper. The Martin Centre, University of Cambridge.

Valkenburg, R. and Dorst, K. (1998) Reflective practice of design teams. *Design Studies,* **19**(3), 249–271.