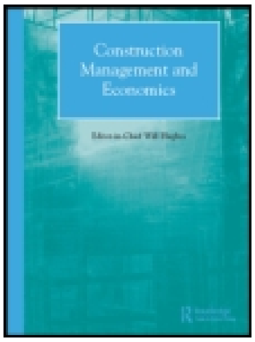

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A quantitative study of post contract award design changes in construction

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The investigation reported forms part of a wider study into the applicability of design for manufacture (DFM) thinking to the total construction process, and the ways in which this could be implemented. Historical data from change order request procedures were examined for several case studies which were considered to be successful projects. These procedures are intended to capture information about design modifications, and thus can be considered to be analogous to the rework procedures used in manufacturing. It was found that in monetary terms alone, the direct cost of post contract design changes amounts to 5.1–7.6% of the total project cost. Although the case studies used here were a convenience sample, the typical financial opportunity for controlling design changes better is likely to be considerably greater than this. Frequently cited reasons for design changes included: employer has changed his requirements, designer's omission in tender documents and new information on existing site conditions. Little commonality between case studies was found at the work package level. In contrast to manufacturing, the availability and accessibility of data relating to rework is problematic.

Keywords: Design for manufacture (DFM), design changes, change order, design, process mapping

Introduction

This paper reports findings from the first stage of a three year LINK-IDAC Project on the development of decision-making tools for controlled innovation in construction, currently being undertaken by Cranfield University and five industrial partners in the construction sector as part of a response to the Latham (1994) Report on improving construction efficiency. The aim was to apply manufacturing concepts, and in particular 'design for manufacture' (DFM), to the construction process.

Background: design for manufacture and the total construction process

Management of the design process in construction has been considered by Gray *et al.* (1994) and McGeorge and Palmer (1997). As a first stage of this study, and in order to highlight similarities and differences between construction and manufacturing, this project sets out to study in a quantitative manner how design evolution, development and modification impact the total construction process and the delivery of a building as a product. The approach was to reverse engineer a number of case histories in order to determine what actually happened to the design during the construction process, and some of the consequences of this. The value of this work lies as much in the approach used as in the findings from the particular case histories studied. The kernel of design for manufacture thinking is to match the design of an artefact to the capabilities of the process that is used to deliver it (Boothroyd, 1994). In manufacturing, this is achieved through a quantitative evaluation of the effect of different designs on production cost, and to realize an appropriate return on investment this needs to be done as early as possible in the product life-cycle (Suh, 1990).

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A recent guide to the construction project process issued by the British Airports Authority (BAA, 1995) set out the following framework.

Project stages
- A: Inception
- B: Feasibility
- C: Concept design
- D: Coordinated design
- E: Production information
- F: Construction
- G: Operation and maintenance

Project activities
- 1: Development management
- 2: Evaluation and approval
- 3: Design management
- 4: Cost management
- 5: Procurement management
- 6: Health and safety
- 7: Implementation and control
- 8: Commission and handover

In this model, all activities can, but need not, occur in each phase, and the phases are separated by clear decision points.

This process model was adopted as an example of modern practice in construction management, to facilitate comparisons between the case studies, and to establish common terminology; it is broadly equivalent to the Royal Institute of British Architects (RIBA, 1992) stages.

The objective of this study

From a design for manufacture perspective, one key question that arises is to what extent activity 3 (design management) in the model does in reality freeze the design at the end of stage E (production information) as the model suggests. Although terminology may differ, every construction project has a management process that seeks to control any modifications of the contract issue design. Considering the design itself as a product, the execution of such a process is analogous to product rework in the manufacturing sector. In manufacturing the metrics associated with product rework are the subject of regular and close scrutiny. Against this background, the objective of this study was to explore in quantitative terms the incidence of all the design modifications after the issue of the contract designs in each case history, and to demonstrate an appropriate analytical approach. In addressing this central question, we also contrast the efficacy of the information delivery systems currently available in construction and manufacturing for supporting this particular process management objective.

An overview of the case histories

Table 1 gives the membership of the professional team that worked on each project, and as the Appendix shows, the case histories differ in many respects. For example, the variety of contracts used to procure the buildings: Cranfield University Library and Aylesbury Shopping Centre. (management contract); Heathrow cargo building (JCT); and the Marks & Spencer Preston refurbishment (Marks & Spencer Design and Construct Version 1). Also, the planned construction periods range from 6 months to 28 months and the total costs were in the range £2.6 – 22 million. The case studies were selected on the basis of being successful projects and on the availability of records from the change order request (COR) procedure. The convenience sample has the advantage of diversity and clearly is biased in favour of well managed projects.

Following a preliminary investigation of project records, the study of the Cranfield Library project was undertaken first, with studies of the Marks & Spencer

Table 1 The professional team for each case history

Project	Cranfield University Library	Heathrow Cargo Warehouse	Marks & Spencer Ltd, Preston	Friar's Centre, Aylesbury
Client	Cranfield University	Lynton/BAA	Marks & Spencer	
Architect	Sir Norman Foster and Partners	Geoffrey Reid		Stanley Bragg
Management Contractor	Taylor Woodrow Management Contracting Ltd (TWMC)		Taylor Woodrow Management Contracting Ltd (TWMC)	
Quantity Surveyor	Davis Langdon & Everest	Franklin and Andrews		
Structural Engineer	Ove Arup & Partners	WSP Consulting		
M&E Engineer	JR Preston	WSP Consulting		

shop refurbishment and extension and the new cargo warehouse at Heathrow proceeding a little later and in parallel. Although the Cranfield Library project was the archetype that helped to shape our approach, the specificity of the analysis of the other case histories was preserved.

The change order request procedure

For the Cranfield Library project the specified procedure for issuing a COR is shown diagrammatically in Figure 1. As every construction project would be expected to have an equivalent procedure, and this was true for each of our case histories, Figure 1 may be taken as generic.

The change order request data

As well as looking at *symptoms* from a quantitative viewpoint this analysis sought, wherever possible, to assign a *cause* to each COR. When a COR is issued, we should like to know: (1) who issued it; (2) why they issued it; (3) when they issued it; (4) what it related to; and (5) what its consequences were, and for whom?

In attempting to answer these simple questions with objective data, three points arise: (a) the details of the procedures used determine the specific data recorded; (b) the record keeping may be incomplete; and (c) the quality of those records that are kept may be high or low. We would anticipate some differences in these respects between and within the case histories.

Typically construction projects are managed in terms of work packages, which may be aligned to specific building elements, specific contractors or some combination of these. Even after the award of a contract, the management contractor may decide to merge or segregate work packages to facilitate better project management. In terms of design management, the proportion of CORs that impinge on more than one work package can be taken as some measure of the success in achieving an appropriate division. Purely as a device to aid presentation, in all subsequent analysis the cost of any COR that affects more than one work package will be shared equally between them.

Given an understanding of the specific management systems in place and a knowledge of the research objectives, the feasibility of gathering and collating data which are believed to exist is essentially a judgement of practicality. Point (a) above leads us to expect that our ability to compare between case histories may be somewhat limited, and this is borne out by Table 2, which is an overall assessment of the degree to which each case history was able to provide the data that was sought, in terms of 'Who, When, Why, Work Package and Cost'.

On the basis of Table 2 it was decided not to progress with the detailed study of the Friar's Centre, Aylesbury, project (but see Tables 1 and 2 and Appendix). Given equivalence with respect to points (b) and (c) above, the Cranfield and Heathrow projects are almost as informative as one another, with the Marks & Spencer project slightly less so.

Working jointly with our partners, our research methodology consisted of gathering all the available COR data for each case history, and then actively reaffirming that the data gathered were intelligible and in accord with the experience of those actively engaged in that project. To facilitate comparisons between projects, any choices as to how to group and label data were resolved with reference to the existing data for the Cranfield Library project.

The empirical results will be presented for each case history separately, followed by a discussion which also contains appropriate comparisons between them.

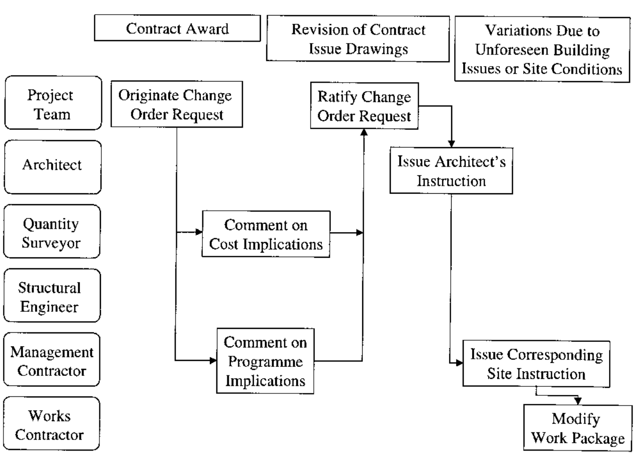

Figure 1 Change order request (COR) procedure

Change order request results for Cranfield Library

The Cranfield Library project was organized into the work packages shown in Table 3, which lists work

Table 2 The availability of data (resolution in time is either day or month)

	Cranfield	Heathrow	Preston	Aylesbury
Who?	Yes	No	No	No
When?	Day	Day	No	Month
Why?	Yes	Yes	Yes	No
Work Package	Yes	Yes	Yes	No
Cost	Yes	Yes	Yes	Yes

package names and numbers, cost and actual start and end dates on site. The total project cost was £4 660 763.

In total 302 CORs were raised, at a cost of £236 985, just over 5% of the total project cost. Ten of the CORs had a negative cost, representing savings to the project. Also, note that work packages 4035 (revolving door), 4040 (solar louvres) and 5070 (carpets) had no CORs raised against them. This means that, in the bar graphs that follow, the sequencing of the bars from left to right is always numeric and corresponds to reading Table 3 from top to bottom with the omission of these work packages.

The number of work packages affected by each of the 302 CORs is presented in Table 4, which shows the frequency of occurrence and also the names of the specific work packages involved when the COR related to more than one work package. As can be seen, 25 CORs involved more than one work package, just over 8% of the CORs by number.

Table 5 shows the reason categories for raising a COR, the empty category being introduced to allow the inclusion of partially incomplete records in the analysis.

The reasons cited for raising CORs and their cost implications, are shown in Figure 2, which is also grouped by the originator of the COR. Similarly, Figure 3 gives the distribution of the cost among the work packages, again grouped by the originator. In terms of total cost, it can be seen that the most important reason categories are E, I and L (forced upon project from shop drawing co-ordination; designer's omission in tender documents; and other), whereas the most important work packages were 5010 and 7010 (blockwork/partitions; and mechanical services), with 7010 by far the most important. Interestingly, the large negative cost in work package 4030 (curtain walling) was mostly because of a decision not to use Okalux glass due to perceived technical limitations for the

Table 4 Frequency of COR's affecting one or more work packages

No. of work packages affected	Work packages	Number of occurrences
1	Various	277
2	3010 5060	1
2	3010 6010	1
2	3010 9010	1
2	4020 4010	1
2	4030 4010	3
2	4030 5061	1
2	5010 5060	2
2	5020 6010	1
2	5060 7010	1
2	6010 6020	1
2	6010 7010	2
2	6010 9010	1
2	7010 5060	1
3	4010 4030 5010	1
3	5060 6010 7010	4
3	5060 7010 9010	1
3	6010 5060 5010	1
4	4020 8010 5020 3010	1

Table 3 Work package costs and timings

Work package name	Work package	Cost	Start	End
Prelims, management fee, staff costs (TWMC)	1000	£612 097	19/08/91	24/09/92
Substructure and concrete frame	3010	£443 854	19/08/91	13/12/91
Roof steelwork and perimeter columns	4010	£259 993	09/12/91	16/01/92
Roofing	4020	£206 250	20/01/92	02/04/92
Curtain walling	4030	£546 536	10/02/92	13/08/92
Revolving door	4035	£546 536	10/02/92	13/08/92
Solar louvres	4040	£125 205	13/07/92	20/08/92
Blockwork/partitions	5010	£228 316	13/01/92	09/07/92
Suspended ceilings	5020	£153 892	04/05/92	10/07/92
Architectural metalwork	5050	£96 494	04/05/92	20/08/92
Furnishings fit-out	5060	£303 780	11/05/92	27/08/92
Carrols and shelving	5061	£320 169	11/05/92	27/08/92
Carpets	5070	£70 379	13/07/92	20/08/92
Electrical services	6010	£345 833	30/03/92	13/08/92
IT/Communications	6020	£102 183	27/04/92	20/08/92
Audio/video equipment	6030	£62 539	27/04/92	20/08/92
Mechanical services	7010	£555 012	09/03/92	27/08/92
Lifts	8010	£51 514	30/04/92	09/07/92
Landscaping/drainage	9010	£145 000	13/07/92	24/09/92

Table 5 COR reason categories

Label	Meaning
A	Improvement resulting from subcontract design
B	Cost saving measures
C	New information on existing site conditions
D	Employer has changed his requirements
E	Forced upon project from shop drawing coordination
F	Programme advantage or assurance
G	Statutory body requirement came to light since placing of trade contract
H	Public utility requirement came to light since placing of trade contract
I	Designers omission in tender documents
J	Coordination defects in tender documents
K	Management contractor omission from packaging
DD	Design development
L	Other
Empty	Not recorded

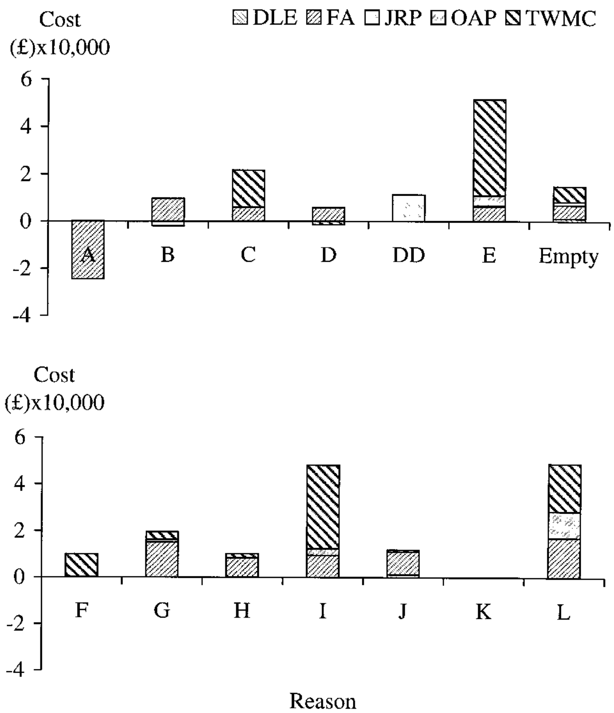

Figure 2 COR costs: why and who (DLE, Davis, Langdon & Everest; FA, Franklin and Andrews; JRP, J.R. Preston; OAP, Ove Arup & Partners; TWMC, Taylor Woodrow Management Contracting)

chosen application, but the corresponding COR was assigned to category A (improvement resulting from subcontract design). Finally, in terms of total costs, Figure 4 completes the picture by giving a breakdown in terms of what and why.

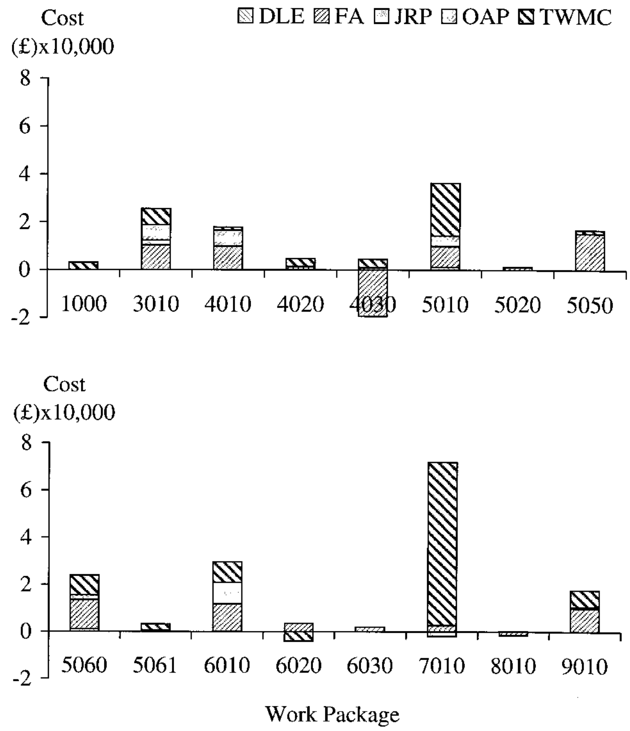

Figure 3 COR costs: what and who

In order to adjust for the different work package costs, the cost of each COR can be divided by the total cost of the work package with which it is associated: Figure 5 shows this, and the vertical axis indicates the fraction of the total work package cost.

Comparing Figures 5 and 3, it can be seen that the rank of work package 7010 (mechanical services) has moved from first to third, that work package 5010 (blockwork/partitions) remains significant, but that work package 5050 (architectural metalwork) is even more important.

Figure 6 shows the number of CORs by work package, and should be compared with Figures 3, 4 and 5, showing that work package 3010 (substructure and concrete frame) consisted of a large number of low value CORs.

Finally it is informative to look at when the CORs were raised. In view of the fact that the project schedule demands different activities at different times in order to facilitate the coordination of work, it is important to use a relative rather than a calendar date in this analysis. For convenience, the actual start and end dates defined in Table 3 were defined as zero and one (which are represented by vertical lines on the x axes in Figures 7–10), and the COR date was normalized to this scale. Figures 7–10 contain examples of the cumulative time plots for interesting work packages against

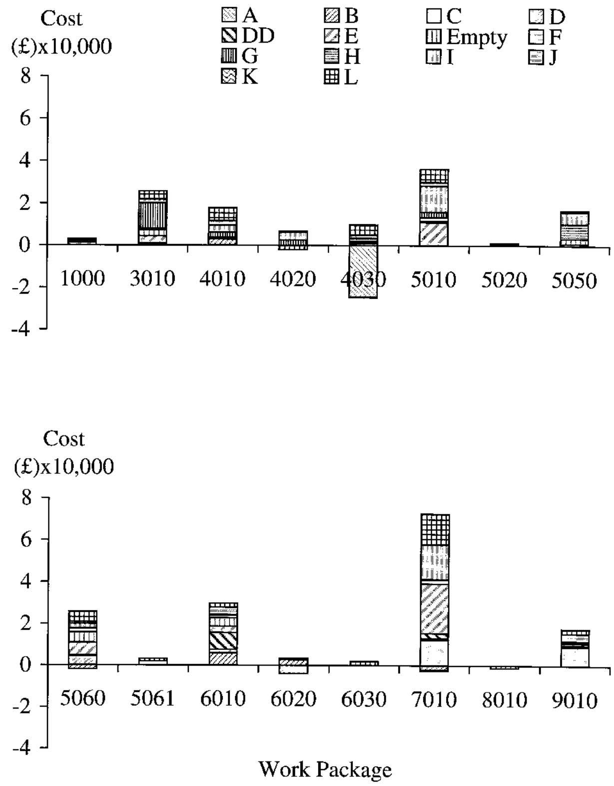

Figure 4 COR costs: what and why

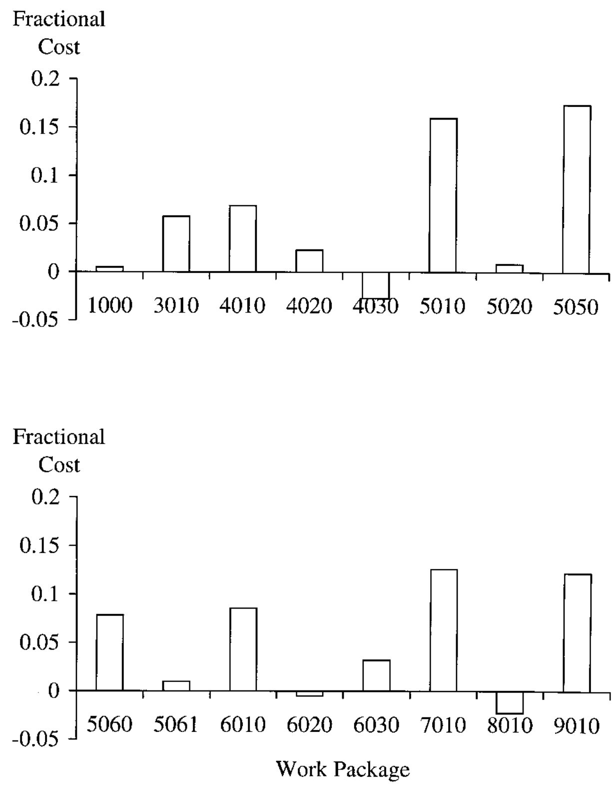

Figure 5 COR costs as a fraction of work package cost

which one or more CORs were raised, shown with a common horizontal scale to facilitate comparisons between work packages. In these figures, the horizontal axis represents relative time, and the vertical axis on the right hand side is the cumulative sum of the number of CORs raised for the specified work package. A vertical step will occur in the trace for cumulative count when more than one COR was raised on the same day. The second vertical axis that appears in the middle of the graph corresponds to the cumulative cost trace, and shows the accompanying cost information (in absolute terms, rather than normalized to the work package cost). Figure 7 shows the occurrence of CORs for work package 7010 (mechanical services), which had the most costly COR sum in absolute terms. It shows clearly that, halfway through the site activity, a number of CORs were raised. Also, about one quarter of the CORs were raised either before the site work started or after it finished. By contrast, Figure 8 for work package 5010 (blockwork/partitions) shows a more linear trend, but with a greater proportion of CORs raised after the theoretical conclusion of site activity. Figure 9 for work package 9010 (landscaping/drainage) shows that half the CORs were raised before site activity started. Figure 10 for work package 4010 (roof steelwork and perimeter columns) shows a similar pattern.

Change order request results for Heathrow cargo warehouse and Marks & Spencer Preston

An equivalent analysis to that performed on the Cranfield Library project was performed on the data pertaining to both the Heathrow cargo warehouse and Marks & Spencer Preston case studies, resulting in similar tables and graphs (which are not presented here). The total project cost of the Heathrow cargo warehouse was £2 603 873. In total 444 CORs were raised, at a cost of £197 084, which is over 7% of the total project cost. Sixteen of the CORs had a negative cost, representing savings to the project and two of the thirty work packages had no CORs raised against them. Unlike the Cranfield Library project (and the Marks & Spencer Preston project), no COR that was raised affected multiple work packages. The reason categories for raising a COR were the same as those given in Table 5, but with the addition of an extra category, M (tenant fit-out). The total project cost for the Marks & Spencer Preston

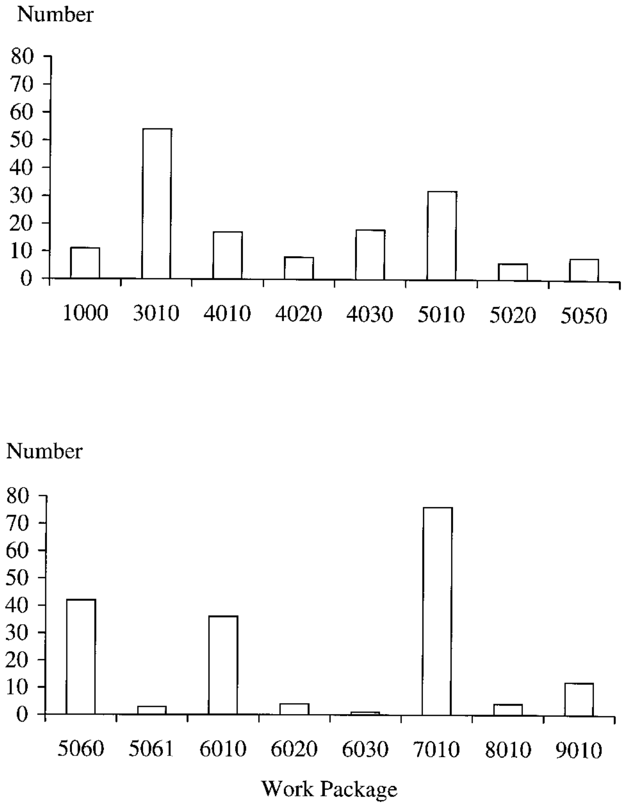

Figure 6 Count of CORs by work package

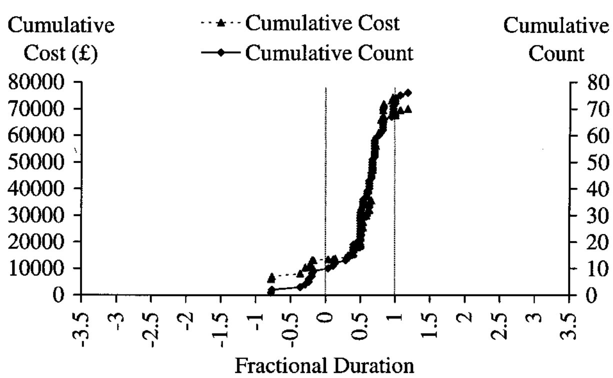

Figure 7 WP 7010 (mechanical services)

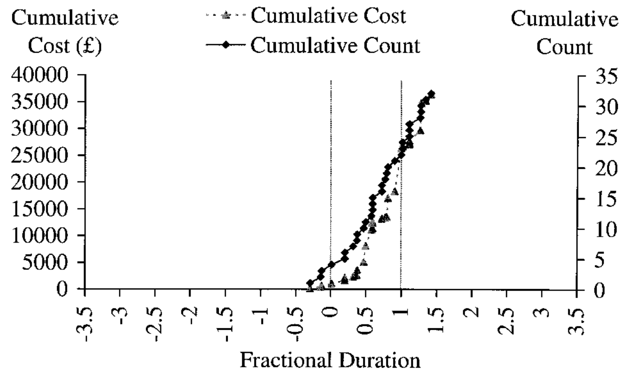

Figure 8 WP 5010 (blockwork/partitions)

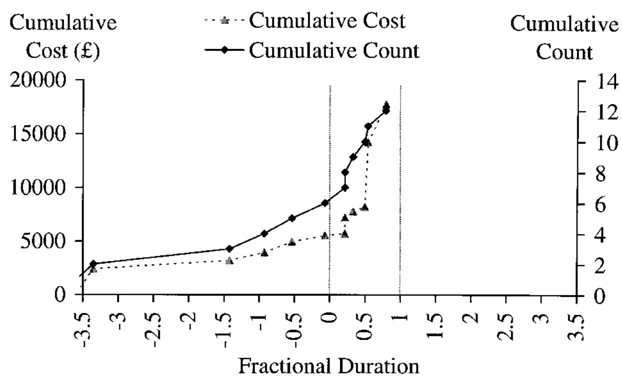

Figure 9 WP 9010 (landscaping/drainage)

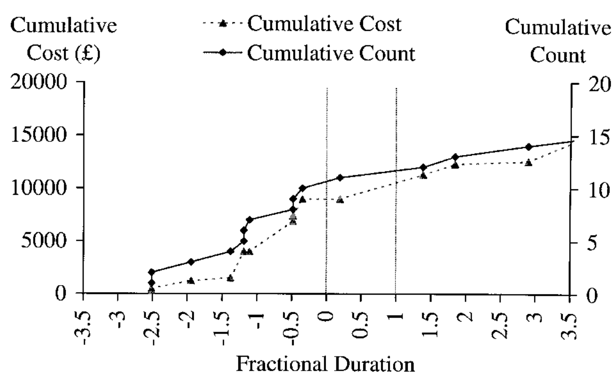

Figure 10 WP 4010 (roof steelwork and perimeter columns)

project was £5 700 732. In total 48 CORs were raised at a total cost of £323 496, representing nearly 6% of the total project cost. None of the CORs was reported as having a negative cost. The level of interference between work packages was much higher than the other case studies, with 37 of the 48 CORs involving multiple work packages, or approximately 75% (compared with 8% in the case of Cranfield Library). Table 2 shows that it was not possible to study the pattern of CORs with respect to their timing or their originator for the Marks & Spencer Preston case history.

Discussion

In this discussion, the case histories are referred to as 'Cranfield, 'Heathrow' and 'Preston' for brevity. The BAA model mandates that the design not be changed beyond the generation of production information and prior to the commencement of construction itself. However, the very existence of a change order request procedure is a recognition that some changes will occur, and our objective was to understand this better and to size the opportunity cost of removing some or all of these changes through the adoption of different design management strategies upstream in the construction process.

The cost to the project of the CORs raised in the three case histories was 5.1–7.6%, confirming the suspicion that, in monetary terms alone, the analysis is targeted at an important feature of the construction process. In gauging the significance of this result, it is important to recall that these figures are underestimates of the costs incurred post contract award for a *typical* construction project. Furthermore the exclusive use of direct cost as a measure of the consequence to the project also must underestimate the real benefit of avoiding some or all of these changes.

The Preston analysis showed the importance of category D (employer has changed his requirements), but this category did not feature so prominently in the other cases (for Cranfield, it was the second least important category). In fact, this feature was recognized in discussions that took place between the contractor and Marks & Spencer Ltd following the conclusion of the Preston project, and has already led to changes in the way joint projects are managed. For Heathrow, category L (other) accounted for about one third of the total cost, and was twice the size of any other category. For Cranfield, this category was ranked second in cost, but was nearly as important as the first category. The second category for Preston was C (new information on existing site conditions), which was ranked fourth for Cranfield and fifth for Heathrow. Category I (designer's omission in tender documents) featured prominently for both Cranfield and Heathrow, while for Cranfield, category E (forced upon project from shop drawing coordination) was the most costly category. In summary, ignoring category L (which is uninformative in identifying root causes for CORs), Table 6 shows the top three reason categories for each project. Note that the third ranked reason for Preston was excluded on the grounds that it contributed a very small cost. Also, although category L (other) does not assist in the classification of the cause of a particular COR, its prominence in the particular case of Heathrow, and also Cranfield, could be indicative of the need for more appropriate data recording.

Turning to which work packages were affected, Table 7 shows the top five work packages for each project (expressing costs not in absolute terms, but as a fraction of the work package cost). In the case of Heathrow, work package 5060 (fitting, furnishings) has been excluded from consideration. There appears to be little commonality in these results as they stand, but this might be the product of using a work package breakdown that is too detailed to show any such trends. However, the exclusive use of coarser groupings would obscure the detailed findings presented here, particularly with respect to the timing of the CORs which are considered next.

The cumulative time plots by work package are an informative display of what happened to each specific work package. The fact that only two case histories gave access to such data means that drawing general conclusions with respect to the timing of CORs affecting particular building elements (for example, steelwork) is difficult. However, this does not detract from the fact that such plots are informative for a specific work package, and that more extensive data gathering would allow any such general patterns to emerge through a study of similar work packages or building elements in other projects. When considering all the work packages in this study, the time profiles show little commonality in their shape within or between projects, but, on average, a large fraction of the CORs are raised either before or after the on-site activity.

Within the limitations imposed by our retrospective study, we wanted to explore the consequences of raising a COR. It is interesting in itself that the only available measure of consequence was the cost impact on the project (and therefore the client). In some instances the concomitant programme implications were asked for, but these were seldom recorded. There is no doubt that, when dispositioning a COR, the scheduling implications and work package interdependence aspects are considered by those that have to make this choice. Unfortunately, these considerations, both in terms of their scope and quality, are inaccessible to the present study, since we have access only to the output of this procedure, when all consequences have been subsumed into the single metric of cost. In addition, it was impossible to assess the consequences to the contractor or subcontractor of a COR that affected their work package. This is a specific example

Table 6 Reason categories for CORs

Heathrow	Cranfield	Preston
I	E	D
D	I	C
J	C	Unimportant

Table 7 Work packages affected by CORs

Heathrow	Cranfield	Preston
External works	Architectural metalwork	Concrete foundation piles
Building services mechanical (2)	Blockwork/partitions	Asbestos removal
Office roof (2)	Mechanical services	Office equipment
Doors and ironmongery (1)	Landscaping/drainage	Overhead and profit
Ceiling finishes	Electrical services	Security

of the general point that the records that are considered to be worth keeping are conditioned by the objective(s) of keeping them which, on the basis of this study at least, are not necessarily aligned with a true process management perspective.

Finally, it is necessary to be aware of the quality of the data available. This is particularly so for a historical study such as this in which the opportunity to resolve ambiguity and answer questions is limited, being at least inversely proportional to the time elapsed since the conclusion of the project.

Conclusion

The main finding is that, even for very successful construction projects, the costs associated with post contract award changes in design (drawings and specification) were 5–8%. Frequent reasons cited are: designer's omission in tender documents; coordination defects in tender documents; forced upon project from shop drawing coordination; employer has changed his requirements; and new information on existing site conditions. It is arguable as to what extent CORs falling into these categories are an inevitable consequence of the construction process itself (so-called common cause variation) or specific problems that could not be foreseen (so-called special cause variation). Part of this debate hinges on where one draws the boundaries of the system, and the attempt to map the design for manufacture paradigm onto the construction process will force further consideration of this issue in later developments of this work. If we distinguish between system and component-level design, as is traditional in a manufacturing assembly operation, it is clear that the incidence of CORs post contract award, but prior to site activity, would be eliminated by the use of standardized building components, leading to immediate gains.

On a more pragmatic note, an incidental but key finding of this work is the difficulty involved in collating data that give rise to metrics which are obvious from a process management perspective (and, indeed, which are readily and routinely available in the manufacturing sector). This could be due to the apparent lack of a desire within the construction sector to advance process understanding in an appropriate way, perhaps because of the fatalistic and adversarial culture that reputedly is widespread, (Rooke and Seymour, 1995). It is interesting that the more enlightened practitioners have long recognized the limitations of this. In conjunction with our partners, we plan to extend the current work through the use of an electronic change order request system. This could allow electronic data interchange between those concerned, and will be designed specifically to assist in root cause identification and a better assessment of the consequence of a COR. This system could be used in real time as a project management tool, and, retrospectively, will allow us to generalize the findings of the current paper to multiple case histories.

This study has demonstrated the value of analysing COR data, utilizing the analytical approach outlined in this paper, for providing insights into the design management and product delivery processes. The method employed provides visibility of the cost profile of design changes with respect to individual work packages, the reasons why CORs were raised and the originators of design changes. The cumulative cost versus fractional duration graphs indicate how the costs of modifications alter with time. Although no definite patterns were identified in this study for specific work packages a larger sample size may yield characteristic curves.

Finally, it is clear that the application of design for manufacture, as practised in manufacturing, to the design of individual building components is conceptually straightforward, and indeed has already been attempted in practice in some instances. Productivity gains and cost savings made this way would be increased if such components were standardized. On the other hand, the application of design for manufacture thinking to system-level design in construction is not at all well understood, and this will be the area for our future research.

Acknowledgements

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Appendix – Profiles of the case histories

Cranfield and Heathrow projects

Table A1 Building details

	Cranfield University Library	Heathrow Cargo Building 549
Project type	Construction	Construction
Building type	Public sector	Commercial for let/lease
Location	Home counties	Heathrow Airport
Floor area	3000 m^2	Warehouses 4400 m^2 Offices 2100 m^2
Height	11 m	–
No. of storeys	3	Offices 4
Type of construction		
Brick		
Steel frame	4	4
Concrete frame	*In situ* concrete substructure and columns	
Cladding	4	Profiled steel
Roof type	Steel truss	Kalzip aluminium
Distinctive features		60 m span trusses to warehouse. Elevated transfer vehicle

Table A2 Construction planning

	Cranfield University library	Heathrow Cargo Building 549
Type of contract	Management contract	JCT
Length of phase		
Planned construction	13 months	9 months
Pre-eng.	6 months	Steel frame components fabricated off-site during construction phase
Time of introduction to project of disciplines		
Structural engineer	Same time as architect	12 months after architect
Quantity surveyor	Before architect	10 months after architect
M&E consult.	1 month after architect	14 months after architect
Others		Contractor: 17 months after architect
Approx. balance of work (by value)		
Off-site	45.7%	–
On-site	54.3%	–
No. of contractors	22 (Inc. management contractor	–
No. of work packages	21	–

Table A3 Design features

	Cranfield University library	Heathrow Cargo Building 549
Level of innovation		
Design	Medium	Medium[a]
Materials	Low	Medium[a]
Assembly	Medium	Medium
Level of architect output from CAD to main contractors	None	None

[a]Building has a high energy efficiency

Table A4 Construction stage

	Cranfield University Library				Heathrow Cargo Building 549			
Site access	Easy				Difficult			
Building access (for fit-out phase)	Easy				Easy			
Compliance with programme								
Work package	Curtain walling	Block work[a]	Fit-out[b]	Mechanical services	Steel frame	Cladding	Fit-out	Mechanical services
Time over (wks)	4	4	3	6 (delay)	1	1	0	0
Programme length (mths)	2½	3	3		–	–	–	–
Cost	–	–	–	–	–	–	–	–
Labour turnover	Not known				Not known			
No. of AI's issued								Cost
	295				164 AI's issued			£6782
					45 Struct. RFI's			£3036
					31 Mech. RFI's			£3200
					17 Elect. RFI's			£1300
					13 Public Health RFI's			£2350
Key personnel who worked together on previous projects	Not known				All new personnel on this project			

[a]Delay caused by delay in curtain walling. [b]Part of delay caused by delay in curtain walling.

Preston and Aylesbury projects

Table A5 Building details

	Marks & Spencer	Aylesbury Shopping Centre
Project type	Refurbishment/extension	
Building type	Retail	Retail
Location	Preston, Lancashire	Aylesbury, Buckinghamshire
Floor area	966 m^2 Extension 5110 m^2 Refurb.	44219 m^2
Height	–	23m
No. of storeys	3	4
Type of construction		
Brick		4
Steel frame	4 (encased in concrete)	4
Concrete Frame		In-situ concrete sub-structure and columns to Mall Level
Cladding	Brick/stonework front	4
Roof type	Flat asphalt on concrete	Steel suspension structure
Distinctive features		

Table A6 Construction planning

	Marks & Spencer	Aylesbury Shopping Centre
Type of contract	Marks & Spencer design & construct version 1	Management contract
Length of phase		
Planned construction	27 weeks	28 months
Pre-eng	11 weeks	12 months
Time of introduction to project of disciplines		
Structural engineer	Pre-tender	At feasibility stage
Quantity surveyor	Pre-tender	At feasibility stage
M&E consult.	Pre-tender	At feasibility stage
Others	Architect, pre-tender	Architect at feasibility stage
Approx balance of work (by value)		
Off-site		30% £8 026 450
On-site		70% £13 595 550
No. of contractors	39	52
No. of work packages	39	84

Table A7 Design features

	Marks & Spencer	Aylesbury Shopping Centre
Level of Innovation		
Design	Medium	Medium
Materials	Low	Medium
Assembly	Medium	Medium
Level of architect output from CAD to main contractors	All drawings by CAD-detailed sketches produced on-site by hand	None

Table A8 Construction stage

	Marks & Spencer	Aylesbury Shopping Centre			
Site access	Difficult	Difficult			
Building access (for fit-out phase)	Difficult	Easy			
Compliance with programme					
Work package	Generally satisfactory	Brickwork services	Roof	External cladding	Mechanical services
Time over (wks)	2, delay to contract	4 wks	8 wks	–	12 wks
Programme length (mths)	–	–	–	–	–
Cost	£150k–to TW	£1.65m	£0.146m	£0.519m	£4.35m
Labour turnover	N/A	Not known			
No. of AI's issued	41 VORF's issued	877 AI's including 607 site directions			
Key personnel who worked together on previous projects	TW commercial mangr and TW project mangr M & S project mangr and TW project mangr TW commercial mangr and assist. quantity surveyor	Architect and quantity surveyor			