Loughborough University

This item was submitted to Loughborough's Institutional Repository (https://dspace.lboro.ac.uk/) by the author and is made available under the following Creative Commons Licence conditions.

creative commons

COMMONS DEED

Attribution-NonCommercial-NoDerivs 2.5

You are free:

- to copy, distribute, display, and perform the work

Under the following conditions:



Attribution. You must attribute the work in the manner specified by the author or licensor.



Noncommercial. You may not use this work for commercial purposes.



No Derivative Works. You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.

This is a human-readable summary of the Legal Code (the full license).

Disclaimer

For the full text of this licence, please go to:
http://creativecommons.org/licenses/by-nc-nd/2.5/

Pre-press manuscript. Citation of the published Work:

Thomson, D.S., Kelly, J.R., & Webb, R.S. (1998). Designing for Short Life: Industry Response to the Proposed Reuse of Building Services Components. In *Cobra'98, RICS Construction and Building Research Conference*, Oxford: Oxford Brookes University, Royal Institution of Chartered Surveyors, 2-3 September.

Designing for Short Life: Industry Response to the Proposed Reuse of Building Services Components

Derek S. Thomson, John R. Kelly, Roy S. Webb

Abstract

Business activity is increasingly subject to influences such as technological advancement and rising consumer expectations which necessitate a flexible approach to working practices particularly in the short-term. Organisations subject to frequent change must be supported by buildings that can readily accommodate changes in the use of internal spaces. Changing the use of a serviced usable space often necessitates alteration of supporting services installations.

The functional, rather than physical, obsolescence of building services components will become more common as the rate of space use change increases. Current practice causes functionally obsolete components to be discarded when altering services installations. Reusing such functionally obsolete components, however, will recover the value of their embodied residual un-depreciated capital investment and under utilised physical life, thereby reducing the cost of services installation alteration and, indirectly, increasing serviced usable space flexibility.

This paper addresses the technical feasibility and economic viability of developing packaged reusable building services components. The use of such components will increase the flexibility of usable space in both new and existing buildings, allowing building operators to better respond to growing user demands for flexible usable serviced space.

Buildings used by the NHS and influences determining the manner of their utilisation are considered representative of commercial building use generally. A questionnaire survey of four potential parties to component reuse: NHS Trusts, specifying consultant engineers, installing contractors and building services component manufacturers is presented. Industry perceptions of the appropriateness of proposed reusable building services components to their emerging needs are reviewed.

The paper presents findings from a two year long study of the Department of Building Engineering and Surveying at Heriot-Watt University. This study is funded by the EPSRC and seeks to determine the technical feasibility and economic viability of developing and utilising packaged reusable building services components initially in the healthcare sector. The paper summarises study findings upon conclusion.

The paper:

- Identifies the potential of reusable building services components to address emerging demands placed upon buildings supporting business function which is increasingly focused on the short-term. The flexibility of new and existing buildings will be increased by reducing the cost of services installation alteration with the use of reusable services components.
- Obtains healthcare sector and construction industry responses to this proposal via the empirical findings of a questionnaire survey of NHS Trusts, consultant specifying engineers, installing contractors and building services component manufacturers.
- Identifies the need for a new industry sector to recondition components recovered from buildings prior to reuse. Suggests component manufacture, procurement, installation, de-installation revisions that may be necessary to establish this support sector.

Keywords

building services; functional obsolescence; reuse; overhauling; remanufacture; standardisation; modularisation; life cycle design; life cycle costing

Introduction

This paper complements the authors' previous work presented at the Cobra '97 conference which proposed that packaged reusable building services components could be developed to service building spaces that are functionally flexible whose use changes in the short term. It has previously been determined that organisations increasingly need to perform their core function in the short term as they respond to increasingly dynamic operating environments (Webb, et. al., 1997). This diminishing stability is emerging due to the combined action of numerous influences including rapidly advancing technology and changing consumer expectations.

The healthcare sector was selected to provide a context for investigation of the implications of this trend. The UK healthcare sector is well defined and, as the National Health Service is a public body, readily approachable. The organisations comprising this sector are simplistically categorised by their function into two groups; healthcare purchasers and healthcare providers. As healthcare providers, NHS trusts utilise the greatest proportion of the NHS estate and accordingly represent the healthcare sector for the purposes of this work. Although determinants of NHS trust function are markedly different from those present in other industrial sectors, their effect is the same. The unstable operating environment which they create is hypothesised to necessitate development of flexibility core function performance. Because core function must be continually amended, NHS trusts must be supported by buildings that can readily accommodate changes in the use of their internal spaces.

A number of architectural solutions to the provision of flexible usable space have been established (consider, for example, open plan offices) facilitating implementation of changes in use without significant building fabric alteration. Often a change in the use of space changes its servicing requirements, necessitating revision of supporting services installations. The physical format of these installations, however, precludes derivation of similar flexible design solutions. To adapt a services installation physical alteration of its constituent components will always be necessary. Hence adaptable, rather than flexible, services installations must be provided. This

research seeks to investigate a potential approach to the construction of such services installations.

Currently, existing components are often discarded when altering services installations. The detrimental cost implications of this practice limits installation adaptability. As organisational core function becomes increasingly flexible, the rate of services installation alteration will rise as will associated detrimental cost consequences. To minimise whole-life costs, and to provide for possible future changes, services installations are often over-provided at the time of building construction. The detrimental capital and revenue cost implications of this practice, however, are significant. A more efficient whole-life approach to servicing buildings is to ensure that services installation duty matches the demands of supported spaces at any given time. The potential energy cost reductions accrued of this practice over the over-provision situation can only be realised if a means is developed of sufficiently reducing the cost of services installation adaptation.

As organisations become increasingly flexible in the performance of their core function the demands placed upon supporting buildings will vary more frequently, resulting in a greater frequency of associated services installation adaptation. This will cause services component removal prior to the expiry of their economic and physical life. It is proposed, therefore, that such functionally obsolete components be reused to recover the value of their residual attributes, thereby reducing the cost of services alteration and consequently increasing services installation adaptability. The Department of Building Engineering and Survey, Heriot-Watt University, Edinburgh is investigating the implications of this proposal supported by a grant from the EPSRC. It is proposed that to facilitate component reuse, current methods of component design, manufacture, installation and removal may require revision. An empirical survey was necessary to determine the construction industry's response to this proposal and to identify the issues requiring to be addressed.

Survey of Industry Response

To undertake the survey, the construction industry was divided into four ‘interest groups’, according to their role in the process of deploying services installations in buildings. The survey focused on those considered to exert greatest influence, although additional types of organisation will influence the deployment of services in buildings. The surveyed groups were: investing clients (represented by NHS trusts), consultant services engineers, services installation contractors and building services component manufacturers.

The survey was administered in a postal questionnaire format. A different questionnaire was developed for each group reflecting their differing responsibilities. Although questions varied, all questionnaires sought to satisfy the following objectives:

1. confirm that building users seek to continually improve the flexibility with which they perform their core function.
2. determine the current extent of building services component reuse and characterise it.
3. determine the response of each group to the proposed reuse of building services components.

4. determine component attributes and deployment methods requiring revision before reuse can be implemented.

Validity of Survey Returns

The availability of information detailing the limited number of NHS trusts (Anon., 1997) facilitated the survey of the entire population. Samples for the three remaining groups were randomly selected from the membership lists of appropriate professional bodies and trade associations. Sample membership was, however, restricted to those organisations capable of undertaking projects of value £500,000 or greater as these organisations, while reflecting the opinion of their smaller counterparts, would provide informed responses.

Interest Group	Number Sent	Usable Returns	
		Frequency	Percent
Investing Clients (NHS Trusts)	485	102	21%
Consultant Services Engineers	279	29	10%
Services Installation Contractors	299	39	13%
Services Component Manufacturers	341	42	12%

TABLE 1: Interest Group Questionnaire Return Proportions

As illustrated by Table 1, sufficient returns were received from each interest group to permit inference of population characteristics from their analysis. Given the use of random sampling, these percentage return proportions are a sufficient measure of return representativity. In the case of NHS trusts a return rate of 21%, twice that of other industry sectors, could be considered indicative of trusts' perceptions of the relevance of the proposal to their needs.

Results

This paper presents those questionnaire analysis findings considered most notable for their importance or unexpectedness.

Nature of Space Use Change in the NHS

To confirm the perceived need for reusable services components, it was necessary to clarify trends in NHS trust building space use. It was necessary to determine the types of building spaces undergoing changes in use, the likely future change in these use patterns, the frequency with which their use is changed and the servicing requirements of those building spaces.

Revision of Organisational Function

As building use patterns are determined by the functions performed within them, NHS trusts were asked to anticipate future changes in their delivery of healthcare services. As illustrated by Table 2, it was observed that the development of greater operational flexibility in healthcare service delivery in the short term impacted the estate. Revisions to core function planned for implementation over the long term, however, are associated with more stable organisational function.

	Envisaged likely future change in provision of healthcare services	Change likely to occur in the short term		Change likely to occur in the long term		Change likely to occur in both the short and long term	
		Freq.	Percent	Freq.	Percent	Freq.	Percent
a.	Adoption of purchaser-led demand response	25	**69%**	8	22%	3	8%
b.	Development of ability to instigate provision of new services and market them on the internal market	18	**55%**	13	39%	2	6%
c.	Specialisation via creation of centres of excellence	19	32%	36	**60%**	5	8%
d.	Specialisation via transfer of non-core services to secondary environment	10	39%	16	**62%**	0	0%
e.	General downsizing in range of healthcare services provided	9	31%	15	**52%**	5	17%

TABLE 2: Extract of Trends in Healthcare Service Provision

Influence of Core Function Revision on Supporting Estate

This divergence in the objectives of NHS trust core function revision has two implications for supporting buildings. In the first instance, greater organisational flexibility in the short term will cause supporting spaces to change more often, thus establishing demand for flexible usable building spaces and adaptable supporting services installations. Secondly, revisions to organisational function planned for implementation in the long term will reduce the range of healthcare services provided. Correspondingly, the size of the NHS estate will reduce and its intensity of use will increase. It is important, therefore, to ensure that methods of implementing building space use changes are optimised and hence demand for adaptable services installations will also be present in the long term.

Built Estate Responses to Organisational Function Revision

To determine the relationship between planned healthcare service developments and corresponding estate revisions, NHS trusts were asked to identify planned amendments of supporting estate. It was determined that, in the short term:

- 19% of estate revisions will result in maintenance of the status quo, representing the inability of existing buildings to respond to changes in their occupiers' core function,
- 12% of estate revisions will cause NHS trusts to optimise their use of existing facilities.

And in the long term:

- 11% of estate revisions will be implemented using existing practices,
- 10% of estate revisions will use the Private Finance Initiative,
- 10% of estate revisions will adopt standard strategic estate planning methods.

Most significantly, 10% of all estate revisions planned over the long term comprise transfer of estate provision from the secondary to the primary healthcare environment.

In both the long and the short term, a trend for rationalisation or other downsizing of the NHS estate is present. Of planned estate revisions, 27% in the short term and 26% in the long term were of this type. This "condensing" of the NHS estate supports the hypothesised need to optimise residual estate use and, consequentially, the need to optimise methods of supporting services installation adaptation. Identification of this trend confirmed the need for the proposed reusable services components.

To further determine the need for reusable building services components, it was necessary to establish the extent to which NHS trusts instigate estate revisions. If they are unable to plan estate development and consequentially have to adopt a response-led role, then reusable services components would provide greatest benefit.

Estate revisions are most commonly necessitated by:

- changes in the demands of healthcare purchasers (16% of identified causative factors),
- the need to respond to changes in delivered healthcare services (9%),
- the need to optimise space use (8%),
- the need to accommodate changing medical practices (8%),
- the need to minimise operating costs (7%).

It was observed that more prominent influences originate from outside trust organisations while the causes of estate revisions instigated by trusts themselves are less influential. The inability of trusts to control external influences necessitate their adoption of responsive roles, thereby necessitating establishment of flexible usable space and, consequentially, associated adaptable supporting services installations. It is therefore concluded that determinants of NHS estate revisions present additional demands for the reuse of building services components.

Types of Usable Space Exhibiting Least Stability of Functional Application

Because different types of usable building space have different servicing requirements, the types of services component most likely to become functionally obsolete, and therefore suitable for reuse, will comprise the services installations supporting usable spaces most frequently changed between uses. The NHS estate is generally considered to comprise two elements; estate supporting healthcare delivery in the secondary, hospital-centric, environment and estate supporting healthcare delivery in the primary, community-centric, environment. Government policy and patient demands are increasing the range and quantity of healthcare services delivered in the primary healthcare environment (Department of Health, 1996). This trend is diminishing the size of the secondary healthcare estate which increases the intensively of its use. Concurrently, the primary estate is becoming more extensive. It is anticipated that services provisions to the secondary estate will need to be optimised while provisions supporting the primary estate will become increasingly difficult to appraise as this estate element becomes increasingly diverse, extending to incorporate GP surgeries and even patients' homes.

Given that the secondary estate has traditionally supported the provision of acute healthcare services, it is hypothesised that their constituent buildings will become more extensively serviced. The intense and optimised approach to using this estate is expected to increase the importance of matching estate provisions to healthcare services provided at any given time. This is not the case, however. When trusts were asked to identify the building spaces most often changed between uses, it became apparent that the most heavily serviced element of the secondary estate was seldom changed. This 'core' element, comprising operating theatres, intensive therapy units, etc., remains relatively static. Its relationship to the surrounding estate is presented in Figure 1. Excluding office and administration space, trusts stated that ward spaces undergo changes in use most frequently. General clinical areas, day care centres and outpatient clinics are changed between uses less often. Building spaces supporting healthcare delivery in the primary environment are seldom changed between uses.

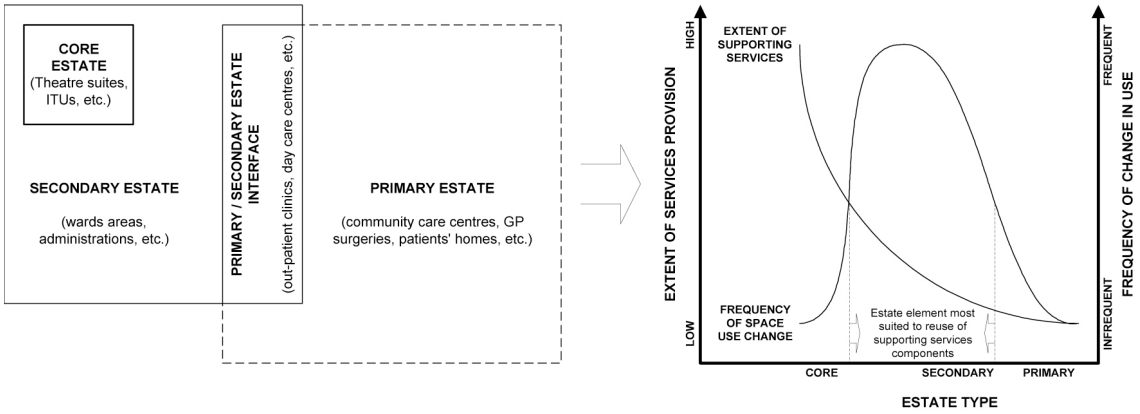


FIGURE 1: Structure of the NHS Estate and Derived Stability of Constituent Usable Space

As illustrated by Figure 1, the stability of NHS estate usage patterns can be represented by a skewed gaussian function. In addition, the servicing requirements of buildings diminishes as healthcare delivery progresses from the core to the primary environment (compare the servicing requirements between of an operating theatre and a GP surgery). By simultaneously plotting space use change probability and building services extent, the types of space whose supporting services installations would most advantageously incorporate reusable building services components was determined.

The Current Extent of Building Services Component Reuse

Before attempting to improve the reusability of building services components, it is necessary to determine the current extent of their reuse. The characteristics of those component types currently reused will provide an indication of the characteristics that may be required of reusable building services components.

Although it is traditionally accepted that the construction industry does not extensively reuse services components, the majority of responding NHS trusts (83%) indicated that they have experience of this practice. This observation is supported by 72% of clients' consultant engineers

who stated that they have reused services components in their designs. Only half (49%) of services installation contractors, however, have implemented this practice suggesting that reuse experience may be limited to particular contractors. Despite this apparent prevalence of services component reuse, it was further determined that only 21% of NHS trusts will exchange components with other organisations to implement reuse. It is therefore concluded that component reuse is restricted by the boundaries of the organisations implementing reuse.

Limitations of Current Component Reuse Practices

Practising reuse within the estates of individual organisations limits the opportunities to reuse functionally obsolete components. The volume of component reuse required to permit incorporation into standard practice necessitates the transfer of functionally obsolete components between organisations. When a component is reused within its originating estate, its history is known. This knowledge of previous component maintenance, reliability, performance, etc. permits assessment of the extent of reconditioning required prior to reuse. It is therefore possible to minimise reconditioning work, thereby increasing potential economic viability. When a component is transferred between organisations, however, this historical knowledge is lost necessitating full reconditioning or overhauling of the component. In other industries, such overhauling prior to reuse permits issue of guarantees of reused component performance. It may be necessary to minimise the costs of overhauling by implementing component design, manufacture and procurement revisions.

In addition to the need to overhaul components to guarantee performance when reused, a number of additional limitations on building services component reuse exist. The survey determined that those NHS trusts who do not currently reuse services components are unable to identify sources of components available for reuse, they are uncertain of the economic viability of the process and, because current component designs do not generally permit up-grading, components available for reuse tend to be technologically obsolete. The most common restriction on component reuse implemented by consultant services engineers is the inability of available components to satisfy current legislation. Consultant engineers are also restricted in their reuse practices by the performance of functionally obsolete components which may be inferior to that of their new counterparts. Implementation of services component reuse by installation contractors is impeded by limited guarantee availability, clients or services engineers who will not permit reuse and concerns regarding economic viability. Given these concerns regarding reuse process economics and the need to overhaul components prior to reuse, it is likely that revision of component designs will be necessary, as proposed. Although these limitation exist, 70% of component manufacturers consider their current products to be capable of undergoing reuse, suggesting an inherent level of component reusability. To ensure economic viability, however, redesign for ease of overhauling will likely be necessary for most component types. Despite the potential need for redesign, 84% of component manufacturers stated a willingness to manufacture more reusable services components.

Sources of Component Reuse Limitations

The survey identified three influences currently limiting building services component reuse:

1. While an increase in the rate of space use change and associated supporting services installation adaptation will increase the likelihood of components becoming functionally obsolete, physical component characteristics may impede reuse. A prerequisite for reuse is durability to ensure that several "installation, removal and overhauling" cycles can be accommodated during the long component life. The materials and design of certain component types will correspondingly require to be addressed.
2. Component sourcing currently impedes reuse given the desire to match components closely to requirements in the interests of efficiency and the diversity of available building services components, in both duty and physical form. Diversity can be reduced by increasing component standardisation and sourcing can be aided by establishing an inter-disciplinary information system.
3. It is essential that components can be up-graded at the time of overhauling to incorporate technological advancements that have occurred during the previous period of use. The revenue implications of continuing to use a component that is less energy efficient than its new counterparts, for example, are likely to be sufficiently severe to prohibit reuse.

Towards the General Reuse of Building Services Components

This section of the paper identifies the measures required to facilitate introduction of services component reuse into standard practice and the implications of implementing each of these measures.

Necessary Component Attributes

To redesign services components to be more reusable it is necessary to determine the attributes of those components commonly reused in other industries which contribute to their ability to be reused. By identifying the types of building services component currently reused the appropriateness of incorporating these attributes into their designs can be determined.

Services engineers and installation contractors were asked to identify the types of component they most often reuse. There was substantial commonality between the component types identified. The types of component currently reused most often were found to be air conditioning plant, pumps and pump sets, electrical power and distribution equipment and boilers. The reuse-enabling physical attributes of these components fall into two categories; those attributes which contribute to component durability and ability to be maintained and those which allow components to be physically moved between installations.

Review of the above component types determined that they are likely to have been regularly maintained during their prior installation. In some instances maintenance and periodic testing will have been imposed by regulatory obligations. Such maintenance minimises the extent of reconditioning or overhauling required before reuse. The need to accommodate rigorous maintenance requirements necessitates that these components types are physically durable and, consequentially, they tend to be of long life. In addition, these component types can be readily identified within and isolated from their surrounding installation (i.e. they are non-bespoke in nature). Compared with services installation elements such as pipework and ductwork runs, the ease of physically relocating these components is apparent. A number of further physical

attributes are likely to improve reusability. These attributes, which include the design approaches of modularisation, standardisation and prefabrication, are beneficial in other industries, but require to be further addressed to determine the contribution they may make to building services component reusability. In addition to exhibiting the above physical characteristics, the types of building services components most often reused were noted to possess substantial residual value at the time of functional obsolescence, aiding the economics of reuse.

The Need for a Support Industry

The establishment of a new industry sector to recover functionally obsolete components from buildings, overhaul them and offer them for sale for reuse with supplied guarantees has previously been suggested (Webb, et. al., op. cit.). Reuse practices in other industries provide an insight into the types of organisation that could potentially perform this function. While this role was traditionally undertaken by specialised organisations to support component reuse in the offshore oil industry, it is noted that original equipment manufacturers are increasingly performing this function (Regan and McCall, 1997), bringing the advantages of access to the technical skills, tools and spare parts required for ease and economy of overhauling. In the office equipment industry, OEMs have performed this role for many years (Azar and Berko-Boateng, 1995, Transmode Consultants, 1993) while in the automobile industry specialised organisations remanufacture individual component types. The variability in the types of organisation implementing the process of reuse in other industries suggests that a similar range of organisation types may be suited to implementing the reuse of building services components. It is not possible, therefore, to pre-empt membership of the support industry based on review of the reuse practices of industries other than construction.

	Component manufacturers' component reuse implementation measure	Proportion of component anufacturers willing to implement measure
a.	Willing to manufacture more reusable building services components	88%
b.	Willing to overhaul components of own original manufacture prior to their reuse	86%
c.	Willing to overhaul components of originally manufactured by others prior to their reuse	43%
d.	Willing to provide guarantee with overhauled components (assuming willingness to manufacture reusable components)	79%
e.	Perceived viability of proposed component reuse supporting industry sector	45%

TABLE 3: Willingness of Services Component Manufacturers to Implement Various Reuse-Enabling Measures

As illustrated by Table 3, the survey determined that 88% of component manufacturers are willing to manufacture more reusable services components while 86% are willing to overhaul components that they originally manufactured to facilitate their reuse. In addition, less than half of component manufacturers consider establishment of a distinct reuse support industry to be viable. This limited support is mainly due to the need to clearly demonstrate the economic viability of new industry sector function. The number of component manufacturers willing to

implement component reuse suggests that they would likely form this new industrial sector. The proposal that component manufacturers would recover and overhaul components regardless of their original manufacturer is not supported. The survey identified component manufacturers' unwillingness to overhaul components other than those which they originally fabricated. This is to be expected given the extent of component design variability and suggests that overhauling may be more effectively carried out by a new organisational type, possessing the more generic skill and knowledge required to process a more diverse range of components than those of a particular manufacturer. At first sight, services maintenance contractors appear to possess these capabilities, as half (50%) of consultant services engineers questioned regarding the organisation types most suited to the reconditioning of components stated that maintenance contractors could perform this role. In contrast 97% of responding services engineers consider original equipment manufacturers to be suited to overhauling components and 72% considered certified agents to be suited. It was accordingly concluded that the most likely members of the support industry would be OEMs although its is noted that in other industries (Regan and McCall, op. cit.) third party specialist organisations have established the support industry with OEM membership occurring at a later stage as a response to reduced new product sales.

In particular circumstances, other industries integrate reuse with the manufacture of new products. Certain manufacturers implement photocopier reuse, for example, by breaking-down returned copiers and recovering those parts likely to be suitable for reuse. These parts, such as motors, optical elements, fusers, etc., are tested to determine their likely performance upon reuse (Azar and Berko-Boateng, op. cit.). If the tests are satisfied, the parts are forwarded to the production line and integrated into new product manufacture. Hence this approach is characterised by loss of reused component identity. The ability to use such an approach is determined the by extent of uniformity present in the installed product base. If a sufficient number of a single product design is currently in use, then this approach becomes feasible as a sufficient quantity of identical products will be recovered.

Extensive diversity in the type, design and duty of installed building services components is likely to prohibit the introduction of such a process (Lund, 1980). It is therefore likely that reuse will be implemented by overhauling components on a singular basis, with retention of component identity. The labour and overhead costs of implementing such a process are significant, causing its economic viability to likely be restricted to components of high value where the cost of the overhauling process remains in appropriate proportion to component value.

Revisions to Procurement Practices

A recent trend in the construction industry is the transfer of design responsibility from services engineers to installation contractors. This trend has arisen with the increased use of performance specifications which permit component selection by installation contractors. It was necessary, therefore, to appraise the extent of design responsibility assumed by installation contractors and the freedom allocated to them to install components of their preference. It was hypothesised that overhauled reusable components could be effectively utilised to satisfy performance specifications as the reconditioning process would facilitate guarantee of performance and such specifications can not explicitly state the need for new components.

Installation contractors were asked to identify how often they developed design solutions to satisfy performance specifications on a semantic differential scale, where scores of 0 and 5 indicated 'never' and 'often' respectively. An aggregate score of 3.270 was obtained indicating that this practice is relatively common although not substantially different from an average score of 3.0. Installation contractors were also asked how able they are to select the components they wish to use to satisfy performance specifications. In this case, a score of 0 represented 'no opportunity' and a score of 5 represented 'free reign'. An aggregate score of 3.765 was obtained indicating that performance specification use increases the likelihood of services installation contractors selecting the components used. To complete analysis of the potential role of performance specifications in the proposed component reuse, contractors were asked to indicate their level of agreement with the statement: "performance specifications facilitate the use of reused components, provided their fitness for purpose is ensured, because system output rather than individual components is specified." Using a scale where 0 represented 'strongly disagree' and 5 represented 'strongly agree', an aggregate score of 2.647 was obtained. The closeness of this score to an average score of 3.0 indicated that installation contractors do not consider performance specifications to be especially relevant to component reuse implementation. Based on these findings, the hypothesis that performance specifications provide a means to implement component reuse could neither be accepted or rejected. However it was established that, where performance specifications are used, installation contractors exert sufficient influence over services design to necessitate development of reusable services components in a manner that satisfies their objectives.

When consultant engineers were asked to identify the potential of performance specifications to implementing component reuse, an aggregate score of 2.172 was received. This compares with the perceptions of installation contractors, clarifying construction industry indifference to the role of performance specifications to implementing component reuse.

A further component procurement process hypothesised to aid reuse implementation is that of component leasing. Although not common in construction, this practice has proven an effective means for OEMs to recover components upon lease termination in other industries (Regan and McCall, 1997). Consultant services engineers were asked to state their perceptions of the extent to which this procurement process would assist component reuse. Using a semantic differential scale, where scores of 0 and 5 indicates that leasing was 'not beneficial' and 'very beneficial' to the implementation of reuse respectively. An aggregate score of 2.333 was obtained causing the hypothesis to be rejected, indicating that services engineers do not consider leasing to be conducive to reuse. However, the advent of P.F.I. has seen practical examples of services component leasing.

Conclusions

By focusing on the UK healthcare sector, this survey has determined that revisions to organisational core function over both the long and the short term necessitate revision of supporting estate provisions which in turn necessitate adaptation of their supporting services installations. Given that the provision of flexible usable building space has been solved architecturally, the need to develop methods to provide supporting services installations has to be established. Diminishing stability in NHS trusts' core function has identified the likelihood of

services components becoming functionally obsolete due to changes in the use of supporting building spaces and, correspondingly, becoming suitable for reuse. To minimise services installation alteration costs, it was proposed that building services components be designed to be more reusable because component reuse will increase the adaptability of services installations by reducing the cost of their adaptation.

The current extent of building services component reuse has been surveyed and determined to be restricted to particular types of component and, more importantly, restrained by the boundaries of organisations originating functionally obsolete components. Survey of services engineers, installation contractors and component manufacturers identified various reasons for this restriction. It was proposed that the primary concern - that knowledge of component history is lost when they are transferred between organisations - will be overcome by overhauling components prior to their reuse. This practice will instigate more widespread component reuse by facilitating the provision of guarantees, but introduces a number of additional issues requiring address such as the need to establish a supporting industry and to determine the economic viability of its function.

The physical attributes of those services components that are currently reused has determined that reuse-enabling characteristics fall into two categories; those that contribute to the ability of a component to be disassociated from surrounding services and those establishing durability and ease of maintenance, thereby minimising the need to overhaul such components prior to reuse. In addition, those components currently reused were observed to exhibit significant residual value. The appropriateness of incorporating similar features into a wider range of components remains to be established. To address factors currently impeding the implementation of component reuse, further work is required to determined the technical feasibility of manufacture and the economic viability of implementing the reuse of a range of building services components types. Further work is also required to determine the economic viability of implementing component reuse by appraising costs and benefits on a life cycle basis.

Given the findings of this survey, and the current extent of component reuse identified as occurring within individual organisations, it is considered that the proposed development of reusable building services components could potentially provide a means to construct the adaptable services installation required to support the increasingly flexible performance of core function demanded by organisations. This is dependent, however, on determining the technical feasibility and economic viability of this proposal.

References

Anon. (1997), *Binley's Directory of NHS Management (Volume 5, No. 1)*, Corringham, Beechwood House Publishing.

Azar, J., Berko-Boateng, V., et. al. (1995), "Agent of Change: Xerox Design-for-Environment Program", *Proceedings of the IEEE International Symposium on Electronics and the Environment*, 1-3 May, Orlando, FL., IEEE.

Department of Health (1996), *Acute Care at Home - Estate Implications (Health Facilities Note, No. 12)*, London, HMSO.

Lund, R. T., et. al. (1980), *Energy Savings Through Remanufacturing: A Pre-Demonstration Study - Interim Progress Report, Center for Policy Alternatives Report Number 80-6*, Massachusetts Institute of Technology, Cambridge, MA.

Regan, C., McCall, M.R. (1997), "The Reuse Market - Is It Worth It? (Paper No. SPE 38516)", *Proceedings of Offshore Europe 97*, 9-12 September, Aberdeen, UK, Society of Petroleum Engineers.

Transmode Consultants, ICF Incorporated (1993). *Reuse and Recycling: Reverse Logistics Opportunities*, Oak Brook, IL, Council of Logistics Management.

Webb, R. S., et. al. (1997), "Designing for Short Life: A study into the development of reusable packaged building services components in the healthcare sector", *Cobra '97 Conference*, 10-12 September, University of Portsmouth, UK, The Royal Institution of Chartered Surveyors.