BIM AND REFURBISHMENT OF EXISTING HEALTHCARE FACILITIES

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ABSTRACT

Towards the end of the 20th century, a growing concern to save nature and natural resources promoted sustainability, which evolved as a major area for global concern. Moreover, an increasing awareness about sustainability in the healthcare sector and construction industry demands more tools for the development, execution, and assessment of projects from environment point of view. To support and assess sustainability, various researchers, governmental and non-governmental organisations developed several tools. Also, it is expected that buildings will have a longer life (especially if constructed from 1980s onwards) because of improved building regulations, modern technologies, advanced tools, and new standards. Project goals, budgets, and clients' willingness towards developing a green facility determines the design team approach towards refurbishment, adoption of tools, and sustainability. Moreover, not all healthcare projects involve new construction; some are partly refurbished and/or extension to existing buildings, so the tools are considered in the context of existing facilities in this paper. Issues and drivers for refurbishment of existing healthcare facilities are discussed from a sustainability point of view. The need for existing healthcare facilities to remain operational during refurbishment projects presents a specific challenge during (re)development. A discussion of some of the widely accepted tools used to develop (sustainable) designs such as building information modelling (BIM) is also presented. The methodology includes a questionnaire survey, interviews, and site visits to hospitals. This work is output of analysis of the primary data collected to accomplish objectives of a three-year research project related to existing healthcare facilities, and reduction of their energy consumption and carbon emissions.

Keywords: BIM, energy, existing healthcare facilities, refurbishment, tools.

INTRODUCTION

Increasing recognition of ‘whole life-cycle cost’, economic efficiency, environmental impact, and sustainability of existing facilities has attracted attention of the research communities, industries, and experts (Kapoor et al., 2006, Monts and Blissett, 1982). The reason behind more consideration being given to the 'whole life-cycle value' and just not initial construction costs in part is driven by the impacts on the environment that buildings have through their life-cycle. The sustainable development of new healthcare facilities has become increasingly important with existing facilities being given greater attention in recent years (Sheth et al 2008). Nevertheless, most existing hospitals still fail to make patients feel comfortable (Lubell, 2008) and many recent healthcare buildings do not demonstrate high quality performance (Mason, 2006) and reduced energy consumption (Sheth et al 2008). With the emergence of issues such as sustainability, there is a growing need to examine the opportunities for improving existing healthcare facilities through strategic problem-solving

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approach to address energy consumption, environmental impact, etc. There has been a recent increase in applications of tools based on the principles of building information modelling (BIM) and simulation for fast and improved delivery of construction projects. One of these tools (BIM) has been considered in this paper from existing healthcare facilities point of view.

The aim of this paper is to identify characteristics features and aspects of refurbishment in existing healthcare facilities. This work is a part of a research project related to existing healthcare facilities. The project explores the refurbishment and/or extension of healthcare facilities especially built in the late 20th century onwards with a key focus being the energy consumption of these facilities. Investigation revealed that early 21st century would observe refurbishment of healthcare facilities constructed in the late 20th century. In addition, during investigation it was revealed that facilities constructed before 1980s and post-Victorian period are inefficient from energy consumption and thermal comfort point of view. Also, most of these facilities are beyond refurbishment thus they are not considered within the scope of this research.

RESEARCH METHODS

To accomplish the aim of the study, a questionnaire survey, face-to-face interviews, and site visits to various hospitals were conducted. The paper is output of the analysis (of few key questions used in the questionnaire) and discussion of data collected using above mentioned methods. The data collection approach helped to collect qualitative evidence related to refurbishment procedures adopted in the industry. The aim of this research is not to develop a certification tool but to integrate and/or to interface existing tools. Thus, building assessment tools such as 'Leadership in Energy and Environmental Design' (LEED), 'Building Research Establishment Environmental Assessment Method' (BREEAM) are not the key focus of this paper as well as this research.

Fundamental reasons behind using qualitative and not quantitative approach are presented below. Quantitative research is uni-dimensional where as qualitative research is diverse (Knight and Ruddock, 2008) which helped to explored more key areas within the boundaries of the research. Within the scope of the research, it was important to investigate how refurbishments projects are executed and the quality of those research projects rather than knowing how many refurbishment projects are executed. Nevertheless, qualitative methods refer to 'what kind' and quantitative methods refer to 'how much of a kind' (Brinkmann and Kvale, 2009). During the initial stages of investigation, it was clear that the refurbishment of existing facilities is becoming increasingly important, but the level, scope, and boundaries of these projects were not clear from the literature review. Thus, the qualitative research methodology was employed.

To justify qualitative research method during data collection 'open-ended' questions were used for the questionnaire survey and the interviews also, the less structured and the freer ranging interviews questions helped to gather the more qualitative data as suggested by Knight and Ruddock (2008). The data collected using qualitative methods are more detailed compared to quantitative methods (Brewer, 2007) which helped to gathered in-depth knowledge of refurbishment. Since, the collected data were qualitative, it was analysed manually and organised with the help of spreadsheets. The use of spreadsheet proved to be useful during analysis to identify drivers presented in Table 1 due to typical nature of data being raw and, spreadsheets were used to organise the data. The data were analysed to identify drivers, types of refurbishment projects, and challenges related to refurbishments in the UK's healthcare sector. Moreover, considering the experience and knowledge of the interview participants and the survey respondents helped to gathered qualitative data providing exclusive knowledge about refurbishment practices observed in the industry.

To conduct interviews and a questionnaire survey, a protocol comprised of three key sections was developed. The three key parts of the protocol were: a background section; a section on current trends in refurbishment with special focus on energy consumption and carbon emission; and a section for feedback, comments related to refurbishment, research project, and client and government policies. The developed protocol was in consideration to principles of qualitative data and tested using a pilot study. During the pilot study a questionnaire was sent to seven selected responded who agreed to participate in the survey. Also, the protocol was discussed with the researcher's supervisors and three colleagues with different background before conducting the interviews and the survey.

The experts involved with development and/or implementation of a proposal for new and/or existing facilities were identified and selected for the questionnaire survey and face-to-face interviews. Selected participants for interviews and the survey respondents were involved exclusively with healthcare projects and had at least 10 years of experience within the healthcare construction industry. To collect the data from the USA, the members of the American College of Healthcare Architects (ACHA) were selected for a questionnaire survey. Whereas to interview and seek the responses from the experts based in the UK, the participants working on NHS and/or PFI hospitals projects were contacted. The primary data collection helped to explore: refurbishment of healthcare facilities; challenges and drivers associated with existing facilities refurbishment; practical approaches; and to identify shortcomings in existing practices related to refurbishment.

As part of the data collection, 43 questionnaires responses, one group interview (with four experts), seven face-to-face interviews, and five site visits were conducted. Considering the limited time frame and other research limitations (such as budget, resources) face-to-face interviews in the UK and an email-based questionnaire survey was sent to the participants from the UK as well as USA. The email-based questionnaire helped to reach selected group of audience irrespective of their location. During the data collection stage, 60 people from industry and 250 registered architects with ACHA were contacted. Out of 250 experts 35 responded whereas, eight responses were received from individuals working on PFI and NHS projects from the UK out of 60 selected for the survey. In addition to the survey, 33 experts were contacted to conduct face-to-face interviews and the researcher managed to conduct 11 (seven individuals and a group interview attended by four experts) interviews in the UK. Also, five site visits were made to ongoing refurbishment projects with the help of the interview participants. This helped to understand more about the refurbishment process and to experience the level of noise, construction dust, etc. during refurbishment.

REFURBISHMENT

The investigation helped to identify various driving factors, several criteria, and scenarios related to the refurbishment of healthcare facilities. This section discusses information gathered from the participants about "how often (after how many years) healthcare facilities are refurbished and why refurbishment is important?"

The experts noted that the changing needs of the healthcare sector demands better and bigger existing facilities, which results in refurbishment. The changes were being driven by various factors and it is difficult to anticipate the changes, scale, or type of construction works which may occur during the life-cycle of a healthcare facility. Large-scale (inpatient) hospitals with several functions have experienced continuous refurbishment, for example, certain departments may undergo refurbishment sooner, compared to other areas in a hospital due to unforeseen conditions or new regulations. In some cases, a hospital building refurbishment may arise over a longer period because of equipment obsolescence or changing technology. Changes to inpatient areas can be due to level/quality of indoor environment, care, and privacy whereas, outpatient areas in a hospital may see refurbishment more frequently because of new technology and demand.

The need for refurbishment in a healthcare facility can vary from 'five years or less' to '40 years or more' depending on the individual organisation's (NHS trust, etc.) goals and objectives. The evidence suggests that the average age of a facility is 40 years with refurbishment occurring on various scales irrespective of locations. Sometimes the physical condition of buildings and changing medical technologies within the buildings demand early refurbishment, even as little as three years after construction, especially in areas which encompass a wide range of medical technologies. In these areas, architectural finishes are also updated at the same time. In hospitals, new service lines parallel with new technologies can influence refurbishment significantly.

The evidence suggests that refurbishment cycles can vary according to purpose, e.g. for skilled nursing homes a five to seven year refurbishment cycle is optimal but usually they are refurbished on a 10 year cycle in the USA. In assisted living facilities, a seven year refurbishment cycle is optimal, but usually they are refurbished on 10 year cycle or longer. Wards facilities for the elderly are refurbished in a decade, although a five year cycle is recommended for partial refurbishment or maintenance in the USA. In facilities with more than 30 year old buildings, refurbishment is triggered by maintenance and\or functional issues. During re-development of hospital buildings constructed in the 1970s and 1980s, there might be a need to consider the presence of hazardous material such as asbestos, cast iron, and galvanised plumbing. Also, a study by Niu (2001) reported presence of hazardous material in many existing buildings, which need to be addressed. Another issue in older buildings is the poor performance of the exterior envelope; many have single-pane glazed windows, poor insulation, and deteriorating envelope.

In addition to above mentioned reasons, replacement and expansion of the services can influence existing facilities resulting in replacement or redecoration of existing built environment. Changing care, delivery of services or medical infrastructure can also be responsible for full or partial new life-cycle of a facility. In some cases, refurbishment is observed due to the constant use of a facility or because the facility has begun to deteriorate. In some existing hospitals accessibility and the 'look and feel' of a facility results in refurbishment.

Equipment is also a key influence, for example a mechanical system with a 15-20 year life-cycle in a building with a 40-50 year life-cycle will require different types of refurbishment at different times. A survey of 21 hospitals in the US revealed that healing environment and aesthetics (including finishes) are not being addressed consistently, and the physical plant and infrastructure to decrease energy usage needs to be considered as a priority.

Refurbishment is important from a sustainability point of view because it protects and recycles (reuses) existing space. It can be less time consuming if, there is no change in usage of the facility as there will be a low risk involved with the (re)-planning compared to change of usage of a facility. In the UK, refurbishment is important to: meet the Department of Health (DoH) targets; achieve energy reductions; and fulfil carbon reduction commitment (CRC) at various levels (such as facility, national, and international level). It can help to achieve current regulations such as 'air changes per hour', or regulations related to indoor environmental quality (IEQ) and if, completed effectively then it can be a cheaper way to provide new technology at lower construction cost in sustainable ways. Also, post refurbishment there can be saving in operational cost, and perspective users (patients, staff, and visitors) have reported improved satisfaction because of effective refurbishment.

Sometimes, facilities are typically refurbished within a decade or two because of additional need of space/bed and inadequate availability of land in the close proximity. With some facilities, refurbishment commences with implementation/development of a master plan, which can have full or partial impact over the existing facilities and infrastructure. However, in some cases, hospital refurbishment is ignored or sidelined and as a result the facilities are beyond maintenance, resulting in need for demolition.

TYPES OF REFURBISHMENT

This section discusses information gathered from the participants about types of refurbishment. The participants were asked to answer "in your experience, what are general levels/types of refurbishment in the context of healthcare facilities? (For example energy, interior re-planning, built environment, mechanical, up-gradation, extension, schedule activity, etc.)." Different types of refurbishment within the healthcare construction industry were identified through investigation are discussed below. As suggested by a participant and revealed during investigation refurbishment projects can be categorised majorly as: interior re-planning; built environment; mechanical; up-gradation; extension; schedule activity; and energy consumption related work.

The type of refurbishment work typically includes addition and/or replacement of old equipment, and periodic improvement of a building's interior; often, new services demand interior re-planning. In some cases, interior re-planning including heating, ventilating, and air conditioning (HVAC), and plumbing along with building's exterior skin/envelope is replaced or redecorated. Depending upon the condition of the buildings and other systems such as lighting, windows, and mechanical systems either technology is upgraded or replaced. There are two reasons for mechanical upgrades: firstly, mechanical systems are at the end of their life-cycle; and secondly, to comply with new/current regulations. In existing buildings energy and mechanical upgrades tend to be cyclic due to a lack of budget for periodical replacement. Building finishes are replaced by more sustainable, approved finishes along with replacement of lighting fixtures. Sometimes major refurbishment involves replacement of windows, roofs, and elevators to improve the overall IEQ and performance of facilities. During major replacement, functional planning is re-considered to improve the patients’ movements and flow, and to reduce staff travel time within the facilities. However, often proposed renovation-cycle with interim evaluation of public areas is considered and not the life-cycle cost despite the increasing recognition of sustainable development and whole life-cycle value. During major refurbishment projects, only the structural system is reused with almost everything else being replaced or improved.

With refurbishment projects, master planning is very important because the level of complexity increases with the age of the buildings. Also, investigation revealed that it is not difficult to refurbish a building less than 20 years old and typically the basic scope of the work would be new finishes, energy saving lighting, better ventilation. Whereas refurbishment of 20-40 years old buildings can be complex in nature with a need for infrastructure improvement including changes in internal as well as external layouts and building's plan. If a building is more than 40 years old, then replacement of the building is considered unless it has a heritage status or cannot be replaced because of dependencies of adjacent facilities. With major refurbishment projects, scope of the work can be divided into following three types:

- 50 per cent re-planning;

- 30 per cent facility interior; and
- 20 per cent of the work is related to mechanical, electrical, plumbing (MEP) up-gradation/replacement.

Two types of approaches for existing facilities were proposed by a respondent: first, frontline services must be considered for improvements; and second, work related to ancillary and support functions. One of the participants presented the following two scenarios associated with refurbishment of existing hospitals interior.

- Scenario One: the vast majority (75 per cent) of the projects are referred as "gut and remodel". Projects under this category demand complete demolition of existing space including finishes, internal partitions, ceilings, fixtures, casework, ductwork, electrical distribution systems, insulation, etc. These projects are usually driven either by a need to add capacity, change in an operational care model, introduction of new equipments or new service line.
- Scenario Two: 25 per cent of projects fall into the category of "redecorating" or finishes upgrades and often, classified as "cosmetic refurbishment" by the industry. The scope is limited to floor finishes, wall treatments and sometime replacement of ceiling and lighting fixtures, and furniture/speciality accents. In this kind of project existing mechanical and electrical systems largely remain untouched. Also, partitions and casework may receive some re-facing.

In both scenarios, the exterior envelope remains mainly untouched. Also, replacement of windows, re-roofing, and envelope improvement are undertaken separately as per their replacement timeframe; life-cycle. Structural systems and entire HVAC are rarely part of any of the above mentioned scenarios however, it is very important to improve structural systems to support major modifications to existing buildings.

DRIVERS FOR REFURBISHMENT

This section discusses information gathered from the participants about refurbishment drivers for healthcare facilities. The participants were asked to answer, "what are the reasons, driving factors for refurbishment? (Increasing demand, age of the building, energy consumption, future extension, scheduled activities, etc.)."

As previously discussed there are several driving factors for refurbishment of healthcare facilities and enquires were made to demonstrate those construction drivers. Many drivers related to refurbishment were identified but due to the complex nature of the drivers it is very difficult to categorise them into specific categories. The drivers indicate the possible range of aspects that could be taken into account towards (sustainable) development of existing healthcare facilities. Three key topics (users', construction, and future drivers) were considered to categorise the identified drivers depending on their importance and characters indicated in Table 1.

User's Drivers indicated in Table 1 can influence existing buildings to undergo refurbishment because of change in perspective users of a facility, such as user pattern, population, profile, needs, etc. Construction Drivers (see Table 1) are due to change or improvement in technologies related to build environment including construction. Whereas, Future Drivers are those drivers which demands refurbishment of existing facilities to support the future needs, new regulations, or modern technologies. If the drivers mentioned in Table 1 are considered during the refurbishment, they can help to identify priority areas, areas for concern, and scope of the refurbishment. Consideration to above listed drivers during refurbishment will define the success and scope of refurbishment projects.

Table 1. Drivers for the refurbishment of existing healthcare facilities

Drivers for refurbishment		
User's drivers	**Construction drivers**	**Future drivers**
New requirements	Building age (structural)	Regulations
Change in demand	Aging infrastructure	New leadership
More demand	Degraded building fabric	Government policies
Standard of care	Functional obsolescence	Technology updates
New operation	Outdated or worn finishes	Competition
New procedures	End of building life systems; HVAC	Change in use
Staff retention	Outdated space	Changing priority
New staffing ratio	Energy consumption	Clinical requirements
Staff recruitment	Lighting	Code compliance
Demographics change	Operational cost	Value for money assessments
Infection control	Maintenance cost	Diagnostic updates
Privacy issues	Complexity issues	Expansion/demand for more space
Outpatient area improvement	Seismic deficiencies	Survey responses
Improvement of patient rooms		Marketability

PARAMETRIC TOOLS FOR REFURBISHMENT

In the last two decades, there been increased interest in the environmental assessment of built environment and sustainability resulting in the development of several tools related to same. These tools help to run the process or to improve the existing process to accomplish expected output. Tools can be classified as a kind of secondary resources to improve the process and to help the design and project team. As the research does not aim to develop a certification/assessment tools (such as LEED, BREEAM) but to integrate and/or to interface existing tools thus, BIM is discussed within this section. BIM is one of the widely accepted parametric tools being used and recommended by many experts (Schneider (2010), Cooper (2008), Fullbrook et al (2006), etc.) on various projects, for several reasons as discussed further. The purposes of these tools are to encourage building design and construction practices to decrease energy consumption and to minimise the impact of buildings on the environment and occupants to achieve overall sustainability. The survey respondents and interview participants were asked to provide information on the application of BIM and simulation for new and refurbishment projects. The responses varied from "adapting slowly" to "no project is done without BIM".

In this section information gathered from the participants about modelling and simulation tools used in the industry is discussed. The participants were asked to answer "are you using any tool (BIM, simulation, etc.), guidance notes, and framework during refurbishment of healthcare facilities? If yes, why and how (for visualisation, energy analysis, to predict performance, on client demand, etc.)?"

Building Information Modelling (BIM)

It was revealed that many experts are using BIM for various problems, such as to calculate staffs travel distance, to predict energy consumption of facilities, and for solar studies. BIM is largely being used for visualisation, construction documentation, and co-ordination between the various consultants and engineers. Also, only 60 per cent of the experts are using it to generate virtual models to be used for various analysis purposes such as energy and for simulation. This kind of tool can be employed on a construction project to: speed up construction; study environmental performance; predict energy demand; compare multiple design options, etc. Primary users of these kinds of tools are architects, environmental, structural, and MEP consultants.

The investigations have revealed that various tools are adopted during the construction and refurbishment of healthcare facilities. Often, parametric tools are employed for visualisation, energy analysis, and improved coordination between the various team members and consultants. Sometimes BIM based tools are used depending on the clients' requirements and scale of the project. The investigation suggests that BIM based tools are often used for large scale and more complex projects. BIM becomes a part of the project throughout the process for documentation purposes and to: generate architectural plans; and provide updated and revised information for the participants in one place. Furthermore, models generated using BIM are used to co-ordinate data created by various consultants, and to minimise conflicts in the future by overlapping the models from different disciplines. As the models are in 3D, they make the design process easier. Often, models generated using BIM are used as a basis for energy simulation and prediction, other simulation studies, quantity take off, scheduling, and phasing of construction work. The model is also capable of generating high quality rendered images for visualisation and presentation purposes. In addition to above benefits, BIM based tools are capable of generating walkthroughs for clients and stakeholders for better understanding and demonstration of projects. During the interviews it was revealed that the tool is an architectural design tool as well as capable of holding large amounts of project (management and documentation) related data. It can be used for benchmarking and other planning purposes such as traffic studies, urban planning, and many other direct or indirect studies related to construction projects and building performance.

Considering the characteristics of BIM based software, they can be used during any stage of the project including operation and maintenance however, they are very effective if used from the initial stages of a project. Also, the project can run smoothly if BIM based/compatible tools are employed. Moreover, they can help to achieve green certificate for buildings' performance such as BREEAM, LEED, etc. Application of BIM can save significant amounts of money and time with the help of virtual mock ups by suppressing the need for physical mock ups. A speciality room mock up using BIM is reported as a great way to mitigate medical staff dissatisfaction. BIM is also used for rapid prototyping in the industry such as patient rooms, consultant (examination) rooms, and typical offices. It is capable of producing, handling, and carrying out comparative studies of several design options at the same time. The tool can be used to reduce significant amount of time by avoiding need for creation of multiple models to be used for various simulation and other studies. Furthermore, during the design stage, it can be used to develop conceptual studies as well as to present the concepts related to proposed facility. In larger facilities the tool can be used for medical and other types of equipments planning.

The development and implementation of BIM in the construction industry is increasing, however, the whole industry is not entirely on board with such technologies. It is reported that many suppliers, contractors, consultants including architectural and design firms are lagging behind compared to other construction organisations who have already adopted BIM. Within the industry some firms have started adopting advance technologies compatible with BIM such as laser scanning to generate the exact BIM model and rendition of the existing building model if client agrees to pay for this. In the later stages of the project, the design model developed at the beginning can be used to justify the requirement and to perform studies related to patient flow during remodelling of existing facilities. These kinds of studies help to understand staff ratio and travel distance for nurses and other staff within the facility and studies can be extended beyond facility level, such as for urban planning.

Some interviewees reported that BIM and simulation tools are not adopted during the projects because of their slow working nature. During the data collection, a respondent reported that BIM is 'ahead of its time' and needs more time to be adopted by the construction industry. In some organisations BIM based tools are being adopted slowly and sometime used to run simulation when operational practices are inefficient. Whereas, other interviewees described BIM as a '21st century tool', employed on all projects irrespective of scale. BIM is capable of resolving clashes between different disciplines such as structural and MEP consultants. As a process, BIM is also capable of assessing building envelope performance, and to make decisions related to same.

DISCUSSION

Refurbishment is an important strategy for extending the life-cycle of existing buildings and ineffective refurbishment can be responsible for reduced life-cycle of existing buildings. Construction work in existing buildings can cost more, less, or equal to new construction depending on the approach of the projects and whether initial cost is considered or whole life-value. In this paper and the investigation presented various components and factors for refurbishments, which will be used to propose and develop a framework for refurbishment of existing hospitals in the future. Many drivers exist which are related to existing buildings, and during any refurbishment projects maximum number of drivers should be evaluated mentioned in Table 1 to ensure success of refurbishment projects.

Some firms have already adapted BIM for master planning and feasibility studies and some are willing to adapt in the near future. The future research and development of the framework will look at the interfacing of various tools and methods during refurbishment to save energy throughout the life-cycle of the facility. The main objective of the framework is to save energy without compromising comfort of the patients. The next step in this research will be to develop and test a framework for assessing and improving the sustainability of existing healthcare facilities, which provides better integration of available tools, guidelines, and standards.

CONCLUSIONS

Several tools and approaches exist in the construction industry but many needs to develop further to suit existing healthcare facilities and, to make effective use of tools, application of these tools should be mandatory. The trend in renovation of existing hospitals indicates that often, aesthetic (redecoration) refurbishment is done more frequently compared to refurbishment of fabric or building services. Moreover, many projects do not consider re-designing and re-planning during refurbishment, resulting in no significant improvement in building performance post-refurbishment. Investigation has revealed lack of a framework or a draft process to be used for application of BIM on refurbishment projects and for existing buildings. The proposed framework is for architects to understand the types of tools, process, and drivers related to refurbishment. Also, facility managers and client can use the framework to keep control over a process, such as by deciding driving factors, etc.

Though age is considered as an important factor in existing buildings, the refurbishment cycle cannot be predicted only on the basis of age. There are several reasons for refurbishment and it is difficult to propose a single solution or a trend. Also, refurbishment is controlled by three major factors: budget, conditions of the system considered for refurbishment, and project's or client's objectives. Investigation revealed that there is a need to consider existing facilities from sustainability point of view and BIM based tools can be very useful for same. Also, though there is an increasing recognition of sustainability still refurbishment projects opt for traditional approach such as consideration to initial cost and not life-cycle cost, and traditional tools like CAD and not BIM.

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