BUILDING INFORMATION MODELLING IN THE FRAMEWORK OF KNOWLEDGE MANAGEMENT: A WATER INDUSTRY CASE STUDY

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ABSTRACT

The UK private water industry has seen a lot of growth in expenditure since privatisation. Ofwat, Defra and DWI have set targets for the water companies to be customer focused, reducing bills, be innovative as well as encourage competition. The emergence of Building Information Modelling (BIM) has offered opportunities to the water industry to achieve cost and programme efficiencies as the rest of the construction industry. This, together with emerging information technology has allowed organisations to take steps in collaborative working, making information available at the right time to the right people, which is fundamental to Knowledge Management (KM). There is limited research in the subject of BIM being used in the context of and tool for KM within the UK water industry. Hence the aim of the study is to explore and understand how the UK water industry is using BIM for KM. A qualitative case study was used for the collection and analysis of data with the results obtained through review of water company supply chain processes, documents, observations and semi structured interviews. The key finding from the study is the significant impact of organisational culture influence on the implementation of BIM & KM in which the water industry supply chain has been aligning its business goals, identifying needed knowledge, creating KM resources and sharing knowledge through BIM as one of KM resources or tools. In conclusion, research identifies that the water industry is heading in the right direction, with leadership and management at the forefront of instilling a positive KM culture, though it is still developing. Ongoing training and provision of resources for KM should continue to be invested in to yield cost, programme, quality and knowledge capture benefits. The close definitions for Information and Knowledge should be taken advantage of for development and implementing of KM strategies using BIM as one of its key tool or resource.

Keywords

Building Information Management, culture, knowledge management, water sector, and implementation.

1. INTRODUCTION

The UK construction sector continued to show signs of slowdown in August 2018 due to uncertainty surrounding Brexit. The civil engineering industry being hardest hit having had a decrease in the amount of work for the first time in five months due to delays on large infrastructure projects. However, UK builders are optimistic for improvements over the next twelve months [10]. This is also shared by Pooley [36] who states that caution continued amongst construction industry players and the Brexit concern remained the show stoppers for strong growth.

The privatised UK water industry operates on five year cycles, called Asset management Period (AMP). Each private water company is regulated by Ofwat, The Water Services Regulation Authority; water companies submit price reviews to Ofwat which detail future plans on delivery customer needs and wants, the latest being PR19, i.e. Price Review 2019. [34]. These Price Reviews form the basis of expenditure for the following AMP cycle [41].

The Drinking Water Inspectorate (DWI), formed in 1990, provides independent reassurance for safe public water supply and acceptable water quality to customers. DEFRA, DWI and the Environment Agency have provided their expectations to water companies for the next five year cycle, AMP7 (2020 – 2025). These include the need for water companies to provide evidence of collaboration and development of creative water supply solutions, together with creating competition which reduces costs and help in developing strategic and innovative solutions [17].

According to the National Audit Office [31], it was expected that the water companies would spend £44 billion, in AMP6, between April 2015 and March 2020, having already spent £126 billion since privatisation. A total of £100 billion is expected to be spent over the next 20 years (HM Government, 2013). Already the water companies are expected to spent £50 billion within the next AMP7 cycle (2020-2025), 13% increase from AMP6. However, household bills are expected to fall due to water companies targeting large leakage reduction, innovation and implementation of efficient measures [20].

At the start of current AMP 6, Ofwat put great emphasis to water companies on meeting future needs based on climate change, growing population which are putting pressure on the water resource. The industry advice [13] put a spotlight on future water management in which water companies need to be innovative and customer focused, lowering of customer water bills, making them key to decision making. Water companies were also advised to protect taxpayer interests, whilst remaining attractive to investors.

Al-Mutaiti, et al, [1] identify a shift towards knowledge based economies, with knowledge now an organisational resource, a driver for economic growth, gaining value over other resources like capital, with the ability to keep a competitive advantage, if used effectively and efficiently [2], [12] and [35]. However, knowledge on its own is not sufficient, it has to be managed effectively in a manner that it is easily available, as and

when required, to the right recipients and in the right format for accessibility.

The Institution of Civil Engineers, [24] stated that the current model used to deliver and operate most of UK infrastructure is broken and often produces assets and networks that are expensive, with poor performance and fail to exploit advances in emerging technology transforming other industries. Dave and Koskela [12] state that due to the fragmentation of the construction industry, and ad-hoc construction project nature, reusing valuable knowledge collected during the construction phase has great challenges. This has led to grave repetition of errors on construction projects with professionals having to keep "reinventing the wheel."

The push by DEFRA, DWI & Ofwat to water companies to show greater collaboration, requires a change from business as usual, yet vast amount of information needs to be shared, securely and effectively amongst project teams/stakeholders. Collaborative knowledge management seems to be the best solution to capture and share construction project based information. Information and communication technologies present several solutions to implement knowledge management solutions [12]. It is a held belief that more integration is needed to support knowledge management and that of business operations [32].

There has been evidence that, use of emerging technology like Building Information Management (BIM) has had positive effect on project delivery; the Manchester Town Hall project, a UK government pilot scheme had nine months programme savings whilst implementing BIM [22]. In today's organisations, a great emphasis has been put on how to identify, capture and share knowledge.

2. BUILDING INFORMATION MODELLING IN WATER

BIM is split into two aspects, information modelling and information management. It is a collaborative way of working, dependent on digital technologies and embeds key asset data and a three dimensional model (Information model). This can be used for efficient and effective information management throughout project lifecycle, from earliest concept design to asset operation and demolition [21].

The Digital Framework Task Group issued the Gemini Principles document which highlights better-informed decisions being made which are leading to improved outcomes. This report names a "digital twin" which is a realistic representation of physical things, that unlocks value enabling improved insights that support better decisions, leading to better outcomes in the physical world [7]. As part of this approach, there is the establishment of the Information Management Framework which is intended to create the necessary building blocks that enable effective information management across the built environment.

The water sector has identified Building Information Modelling (BIM) as crucial to the current digital transformation need, it is a business change which takes years to fully embed. BIM requires an investment in the process, people and systems in order to fully yield the benefits. The water sector, through BIM4Water task group identifies BIM as Better Information Management across the life cycle of an asset, recognising the move to a data driven digital world; this indicates a shift from the traditional ways of managing data, information and knowledge [5].

It is apparent that the importance of knowledge as a major project resource [12], and BIM as an enabler for knowledge management has great benefits which include (a) staying ahead of competition, (b) reduce project costs (c) shorten project programmes (d) increases productivity (e) encourages collaboration (f) drives innovation and (g) enables better information and knowledge management [5].

BIM also has potential to provide advanced knowledge management intended to enable sustainability and asset management matters in design, construction, asset management practices and decommissioning for the civil engineering industry [25].

The water companies commitment to Ofwat will need the water companies and its supply chain to collect, store, process, exchange, maintain asset data, information, knowledge and manage it in order to show that the outputs meet the promise made during the price reviews [40].

There is also a need to show innovation, efficiency, better information management and to meet the drive for a "Digital Britain." BIM as an enabler for KM will enable the water companies and its supply chain to meet these requirements and its commitments, though with challenges, as it is a shift from business as usual. It will drive innovation, reducing costs & wastage, and improves project delivery whilst capturing all information [22]. The text should be in two 8.45 cm (3.33") columns with a .83 cm (.33") gutter.

3. KNOWLEDGE MANAGEMENT IN THE WATER INDUSTRY

Becerra-Fernandez and Sabherwal [4] point out knowledge as being the highest level in a hierarchy with information in the middle and data at the lowest level. They state that knowledge is intrinsically similar to information and data, though the richest and deepest and is the most valuable.

Despite collecting great amount of information through various Information Technology (IT) systems, there is a belief that the most significant information in a water business, or any other utility, is carried around in employees' brains, with estimation of around 70%, 80% and others saying 90%. This in itself, is enough for businesses to pay attention to Knowledge Management (KM) as stated by Lee Odell, who has been CH2M Hill's Vice President and Water Treatment Global Technology Lead for the past 12 years [33].

Becerra-Fernandez and Sabherwal [4] define KM as undertaking needed activities to get the full benefit of knowledge resources. It improves the way organisations work with data and information, and helps collaboration by allowing people to share knowledge [26]. To support this, Odell [33] defines it as fostering the use of the right information within an organisation to make best decisions. The management of knowledge, generated throughout the project lifecycles, has been implemented by various organisations through development of lessons learnt registers, project close our reviews and other informal techniques [15]. Information Technology has provided a significant impetus for the enabling the implementation of KM applications, which has allowed deployment of sophisticated technologies [4].

The fast changes taking place in the KM field is attributed to the dramatic progress in the IT field, which facilitates knowledge sharing, and its growth through increasing speed and efficiencies of information movement [4]. The water industry has since

adopted BIM technology and methodology to manage project information [5], and KM can provide very beneficial understandings and methodologies to aid in BIM implementation [14], and [26]. BIM, coupled with cloud based approach, was used for the Sandon Dock treatment works, undertaken by the joint venture of Galliford Try Costain Atkins (GCA) for United Utilities [15] and [38]. GCA's approach was to get the right information to the right people at the right time and in the right format; BIM applications demonstrated the ability to meet these requirements as stated by [6].

Malone [26] states that the KM concepts useful in BIM implementation are DIKW (Data, Information, Knowledge and Wisdom) hierarchy and the differences between explicit and tacit knowledge. Data are facts, observations or perceptions (correct or incorrect) and information is a subset of data, only having data with context, relevance and purpose. Information includes manipulation of raw data to obtain a meaningful indication of data trends. Knowledge is information that enables action and decisions to be made or information with direction [4].

Knowledge is split into two, tacit and explicit. Explicit knowledge is knowledge that can be easily captured, written down and stored whereas tacit knowledge is more difficult to capture, largely remains unspoken, and usually learned through experience or training and informs one's decisions [26] and [33].

The research by Deshpande, et al, [14] identified the use of BIM as an effective tool of knowledge store which can provide support to KM processes during a project lifecycle from design to construction. Smith [38] states that one of the BIM adopted definitions is "Better Information Management" which is also preferred by water industry BIM task group [5].

4. RESEARCH METHODOLOGY

Naoum [30] highlights a need for a research to be conducted to correspond with the needed data availability. The data in question was perceptions and experiences on BIM implementation in the context of KM, and effects on the delivery of construction projects. The research aim and objectives pointed towards an investigative research approach as there is limited research in BIM implementation in the context of KM for water projects. As Naoum [30] highlighted, a need for to conduct a research should correspond with the needed data availability. Hence a qualitative research approach was selected. A qualitative research approach focuses primarily on the evidence that a researcher is able to understand what is going on by what people say or what they do [18].

A case study approach was selected as it is a comprehensive methodology and incorporates multiple data sources to provide detailed account of complex research phenomena in real life context [27] and is a viable way of carrying out qualitative research strategy and involve in-depth exploration [10]. A case study approach is used to support arguments by carrying out an in-depth analysis of a person, organisation or groups or a project focusing on one aspect of a problem. However, these are not generalised [30] which is regarded as lack of validity. Hence conclusions are related to a particular event and an in-depth analysis of a specific issue. The data collection and in-depth analysis were carried out through review of water company supply chain processes, documents, observations and semi structured interviews of five project participants based on theoretical sampling technique. The analysis of the interviews was undertaken using Content Analysis. This type of analysis is practical when semi-structured questions are used in soliciting information, because it allows for defining content categories through coding. Selecting and defining categories (codes) is analogous to treating semi-structured questions as if they were closed-ended in survey research.

5. WATER PROJECTS DELIVERY IN KM AND BIM CONTEXT

5.1 Water Industry Frameworks

Customers' water supply is normally through their local monopoly water company, however, latest advise has been to remove barriers to competition, sustain innovation and efficiency and allow new water industry players to improve customer service (Defra, 2011). According to Ofwat and Defra [42] and DWI [16] the current UK water industry infrastructure and knowledge emanated from the industrial development dating back to the early nineteenth century. This has led to virtually every household benefiting from a reliable, efficient and effective water industry with piped water supply of very high quality and connection to sewerage systems in England and Wales.

The UK water industry includes 18 large regional independently operated private companies which provides water services funded by their customers through private investment financing. As in October 2015, the water industry had 22 million household customers and two million non-household customers in England and Wales. [31]. In England alone, there are nine large water companies covering different geographical regions providing both water and sewerage services. There are other twelve water companies that provide "water only" services [23] and [40].

The policy and regulatory frameworks for the water industry in England and Wales are set by Defra as well as the Welsh government. Independent regulation is enforced by the Water Services Regulation Authority (Ofwat) who protect consumer interests, limits prices, ensure companies carry out their duties as well as securing long term resilience of water supply and wastewater systems. [31].

Price Water Coopers (PwC) [37] stated that most of the water sector has long established long-term frameworks or alliances for the delivery of capital projects. These frameworks enable water companies to obtain support with the design and selection of solutions and delivery of projects to maintain their assets.

PwC [37] stated that large water companies have been through the process of undertaking all capital project delivery activities inhouse i.e. design, engineering and construction management, themselves through to outsourcing the whole scope to delivery partners. A lack of balance between in-house and outsourcing can lead to longer project durations, lots of changes and rework during construction, poor and unmeasured engineering productivity, lack of technical innovation or projects not realising the expected benefits. Getting the price right can no longer be viewed as the benchmark for managing the water companies supply chain, but measured against delivering all of the set criteria, internally and externally for Ofwat, DWI and Defra, [31].

Implementing BIM not only will yield cost savings, reducing customer bills, but will enable KM practices to be adopted, in part. [38]. Project information is able to be stored, managed and made available at the right time to the right recipients in delivering projects achieving project efficiencies. For this study, project delivery processes were reviewed, including documents,

approaches and interviewees asked to discuss project KM and BIM application implications.

5.2 Fostering KM in Organisations' Cultures

Back in 2010, Mounce, et al, [28] saw the management and sharing of complex data, information and knowledge as a fundamental and growing concern in the water industry. The use of information systems were identified as conduits to identify, capture and manage knowledge to address this concern. However, best practice focus was placed primarily on organisational improvement rather than technology [19].

The Chartered Managers Institute, [9] defines the organisational culture as its personality and character; it is how things are done in an organisation. It is made up of shared values, beliefs and assumptions on how (a) people should behave and interact, (b) how decisions should be made, and (c) how activities should be carried out. Organisation's structure, value and traditions, work systems and processes, employees' behaviours and attitudes, and adopted leadership and management styles influence organisational cultures.

In this study, the organisational cultures were identified to influence how projects were delivered and the extent of KM and BIM application. At project inception there was emphasis by leadership and management to review lessons learnt registers, internally shared bulletins, documents and other best practice guidance. Likewise, during project progressions, project participants were encouraged to produce and issue these so that information and knowledge can continue to be shared across the organisation. One example cited by an interviewee included "using information and knowledge from a previous similar project to shorten programme, reduce cost and reuse of available information to progress design, identify and manage project risks as well as identifying and engaging external stakeholders early". On further review of this example, both explicit knowledge (from records) and tacit knowledge (in the mind of the knower) were obtained. Face to face conversations were held to discuss and share past scheme findings, best practice and lessons learnt. This is supported by [33] who states that KM is about sharing greater level of tacit knowledge in order to make better informed decisions.

This approach by leadership and management fosters KM implementation initiatives, aligning them with evolving organisation goals. In one organisation, presentations are being carried out regularly attended by employees sharing information and knowledge relevant to subject areas. A culture of sharing knowledge and information using IT, business social media and peer reviews has been known to facilitate knowledge share and retaining of business, technical and operational knowledge. Another interviewee pointed out "knowledge and experience being captured by a developed culture of positive intervention which covers all aspects of an organisation's operations being developed, used and used to capture good practice, and interventions". The findings from this study are shared by Deshpande et al, [14] who highlight that social systems which include lessons learnt programs, post project reviews and the IT tools used for knowledge sharing are complimentary to each other. Even though information produced in a construction project is in various formats, with limitations, Dave and Koskela [12] warn not to underestimate the impact of IT tools, including BIM, for KM.

One of the key findings from the study is the great emphasis placed in training and mentoring junior staff to retain knowledge. Of those interviewed, highlighted availability of training for all staff, to enhance and retain knowledge. Apprentices and junior staff had assigned mentor who are senior within their areas of expertise. One graduate engineer on a training programme stated that not only did a structured training programme fulfil the organisation's requirements but also enabled him to gain knowledge and experience to be a better engineer preparing for chartership. This was seen as one of the best ways of capturing and retaining the "tacit" knowledge and to support KM within an organisation.

5.3 Identifying Knowledge and Creating Resources for KM

The drivers for knowledge management implementation were noted as (a) realisation of knowledge drain from an organisation when senior staff left without knowledge transfer to junior staff (b) loss of knowledge as an organisation grew (c) need to remove cultural barriers that hinder knowledge sharing (d) Capitalisation of organisation knowledge by creating dedicated training (e) Meeting required increased accountability and transparency and (f) keeping knowledge and innovation being regarded as key to an organisation's sustainability [29] and [33]. This was discovered within this study, with key factors being staff departures, reassignments on promotions and other project factors with need for prioritisation and making experienced staff unavailable to pass on their knowledge. However, one interviewee stated that "the current way to capture the experienced staff knowledge (tacit) is usually through handovers though this does not go the full length as some of the knowledge isn't mentioned during the face to face meetings". These meetings are followed by handover emails, with the aim to provide pointers to where project information or knowledge can be found and openness to provide answers when required. The latter is usually difficult if the experienced staff with the knowledge is not available or tied up with something more important when answers are required to previous decisions.

The key finding of the study was the reliance on BIM for retaining and managing project delivery information. HM Government [21] regard BIM's information model as a tool and resource used for efficient and effective information management allowing collaborative working. Some BIM technicians are learning to make independent decisions because of the knowledge they are gaining, as one said, "I am enjoying the benefits of all information being in one area so that we can get it right first time." IT systems have brought great opportunities that are being exploited for project knowledge management, bulletins have been shared on the vast benefits mentioned above in knowledge sharing and eventually ending up in BIM models. This is allowing knowledge and information to be retained within the project team when one of the "knowledge holders" leaves the project as stated by the interviewee. This is in line with DDA [15] and [38] who highlighted that BIM implementation allows sharing of information and encourages a more collaborative approach with better information management.

It is apparent from the above there exists a relationship between BIM and KM as stated by Malone [26]. He goes further and states that KM ensures that there is no narrow focus on management of data and information, which weakens the recognition of the importance of broader knowledge processes critical and essential to effective project delivery. The organisations in this particular study were using IT systems which included Autodesk Revit, revizto, Autodesk Navisworks for

project delivery as BIM tools, creating tools for KM. These IT systems, coupled with cloud based platforms, e.g. ProjectWise, identified in this study, allowed effective collaborative information and knowledge management. This was supported by [12] who highlighted collaborative knowledge management as the most suitable solution to capture project based knowledge with information and communication technologies, like BIM tools, offering several solutions. Two of the water companies in the study area took further steps and invested in procuring IT systems to create virtual environments for any project site. These allowed to a 360 view to view and walk through sites, design, construction in three dimensions whilst in the office viewing drawings, images or BIM models which are regarded as knowledge systems regarding how things are constructed [3].

The BIM Hub [39] goes on further to state that BIM is rapidly gaining traction and is seeing increased implementation in the water industry. This has led to enhanced multi-party collaboration of project teams, reduced conflicts, better ability to maintain quality and better communication from 3D visualisations which is supported by the interviewees and review of the project delivery processes. The organisations have set processes for information and knowledge capture and management using BIM which include online skills matrices both for identifying experts in the organisation as well other tools to use for project delivery. There are also identified experts, the go to for different subject areas, BIM included. There is now an assigned BIM Manager dedicated for water projects in one of the organisations with a working group responsible for keeping up to date with emerging IT and BIM tools and sharing with the respective teams. The study identified that BIM has the ability of enhancing collaboration across project teams and beyond is a critical way it creates value on water projects which is shared by DDA [15].

5.4 Knowledge Share

One of the key features of KM is organising a routine way of sharing information, in the right format, with people who are able to make best use of it [33]. There were various forms of information and knowledge sharing identified during the study, formally and informally. One interviewee was moved to sit next to his mentor so that he had quick access to the information and knowledge that he required. He stated that it was easier and quicker to ask any questions since the mentor was next him, this was different when they sat in different locations in the office. There were able to discuss where information can be obtained on the cloud based IT systems, mentoring and on the job training using respective industry design software, e.g. ArcGIS, Autodesk suite tools including BIM applicability.

It was apparent during the study that BIM applicability was being tailored to project delivery and was became paramount. Crofty [11] back in 2012, stated that BIM had become a contemporary issue, becoming the most debated and discussed topics in construction. These discussions were based on what BIM is, its benefits and how to use it, which were the issues the industry needed to address at the time. In the longer term, the industry needed to identify how it responds to the capability of constructing with perfect information; focusing more on what BIM can do for the construction industry and less about what can be done with it. For two organisations, BIM had become a knowledge hub that was used to disseminate or share project knowledge in formats suitable to recipients, answering the question, “what can BIM do for us?” Information and knowledge in the form of two and three-dimensional drawings/models, elements and equipment schedules, cost build up, programming and even health and safety consideration and deliverables were being produced in respective formats for different team members.

Crofty [11] stated that implementing BIM allows achievement of greater quality design information and enables greater quality, more efficient communication amongst project team members systems by using clear and effective data exchange standards. The organisations also used BIM models for clash detection and avoidance of existing assets, allowing design communication for different disciplines, the models had become design knowledge hubs for KM. A BIM Technician in one organisation was issuing three dimensional drawings embedded in pdf software for comments to be made by designers and stakeholders who did not have the modelling software. This was greatly welcomed by the water companies site operators as they could see and agree to the asset configuration they would be getting, highlighting and concerns early.

Another benefit of BIM influence on KM was on planning drawings which now include three-dimensional models to better communicate the project information. These form the building blocks, that can then be used to better communicate project intentions in a format easily understandable to non-technical people. For technical project and non-project participants, design and construction drawings are easily extracted and shared. Equipment and element schedules are extracted from the BIM model and issued to enable procurement, ensuring right information is sent out and the site receives correct building elements. However, the challenge is to ensure that the input into the model is correct and that they comply with respective specifications. Hence, design and project information and input for model build up and management is reliant not only on the knowledge and skills of technician, but on the sources of information. This study identified that reference was made to organisations’ internal and external standards and specifications, information provided by suppliers and subcontractors as well as knowledge and information from designers. This in itself revealed the key reliance of project teams to explicit knowledge management using IT systems, BIM being key on communication of project outcomes.

6. CONCLUSION

The UK water industry is private and relies on the technical expertise and resources of both itself and its supply chain to meet regulator set standards and goals. The main targets being to be customer focused, delivering best customer support, innovative, including use of emerging technology and encourage competition. The use of BIM, though not mandatory, on water projects has increased in order to meet these targets as well as well keeping up with construction industry trends to achieve the efficiencies. The key benefit of BIM is the collaborative working it brings and allows sharing of information and knowledge amongst project members. It was identified that KM is not a prevalent term in the water industry in itself but it is embedded in the day to day project activities and set processes and procedures, including BIM used as one of its tools.

Organisations within the UK water industry have been implementing KM in order to prevent loss of knowledge due to staff movements, in and out. The study identified the water industry supply chain has been aligning its business goals, identifying needed knowledge, creating KM resources and sharing knowledge for KM with BIM used as one of its tools. The key aspect being organisational culture that offers and encourages KM practices to be implemented from project inception to completion.

Leadership and management have taken the initiative to remind staff of the importance of knowledge capture and share at the right times, to the right people. However, this is an ongoing process with continuous staff training, procurement of IT systems and collaborative working. This is enabling organisations to capture both "tacit" and "explicit" knowledge, with the latter usually in the form of tangible deliverables. BIM, as part of KM is allowing capture and retaining project delivery knowledge with inputs from the supply chain as well as project participants who refer to online platforms used for knowledge store and sharing. There is a need to further highlight the subject of KM within the water industry, in the context of BIM which is a contemporary issue. The interchanging and close definitions for Information and Knowledge can be taken advantage of for development and implementing of KM strategies using BIM as one of its key tool or resource.

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