CAD systems put forward developed drawing abilities but hardly ever include the human element, for instance, simple geometrical shapes, because they are do not have proper semantic organisation. The aims of BIMs were twofold; firstly, to design a model that includes depictions of objects in order that the physical world can be shown semantically. The other aim was to provide a database of applicable information that could be used to assist those working in the construction field. Since its inception, BIM has been championed by construction experts for dealing with many longstanding problems. Indeed, BIM software on its own is sufficient to meet the requirements of construction experts. However, given the need for applicable expert assessment, many would like to see BIM combined with the spreading of semantic data.

To adapt to the constantly changing IT world, BIM systems need to become more flexible. They must also become more objective, to include both the analysis of experts and the information gathering methodology. Quantity differences have been reduced because of 'smart building technologies' and 'building information models,' and buildingSMART is derived from IFC to manage quantities emanating from BIM applications.

Those carrying out this research would like to establish a system based on knowledge that links with the advances of BIM. The improvement intends to deal with two widely-recognised problems within the area of cost estimation: P1: compliance with domain standards and P2: the use of personal opinions.

This research paper will first give an overview of the cost estimation semantic model. The methodology used to carry out this research will then be examined before the suggestions being put forward are examined. The iilustrative results will then be given and resulting discussion and conclusions will complete the paper.

2. Background

As a result of technological advances in IT, many software applications have been created and used in relation to construction cost estimates. These include Sage Timberline [6], Innovaya Visual Estimating [7], CostX [8], and Nomitech [9]. Nonetheless, there are drawbacks in the use of this software in the cost estimation process; in BIM cases [10–13], and quantity surveyor cases [14–20], pertinent details still need to be taken from the model, or a 3D model built with the particular purpose of estimating costs. This is all a slow and error-likely procedure; after building the model, measurements must be taken by satisfying specific requirements, such as SMM [21] or Professional Practice Guides [22], to arrive at a priced unit figure. This quantity surveying is difficult and hard to follow through accurately [4].

The most usual type of knowledge representation language used is OWL, although studying the estimates given emphasise that there are four semantic models used. Using OWL as a knowledge representation language for descriptive information is the best known and most widely used. Nonetheless, it is important to point out that this use ignores any concerns in relation to language. As noted by Grzybek et al. (2014), problems show up because there is the lack of a proper link between semantics and practical decisions with systems of knowledge engineering. Therefore, it is necessary to have a more detailed assessment of the results of the estimating process [1–5].

The implementation procedure can be understood as making the elements of the component from symbols of the building product replica, such as the IFC-based model, to pinpoint how these elements are made, and using the advice of construction experts in a standalone capacity to measure or add tasks for building components. The cost figure is then altered to take into account the impact of these changes. The ontology also uses a classification scheme which organises the information into a tree structure. There is a parent node for each node, and each parent node might have many children nodes. Moreover, each child node is a sub-category of the parent node and makes it easier to categorise more precisely. The emphasis is on the condition of the design and the impact this has on price. Despite the classification structure being clearly identified, the language for the model is not specific enough.

The improvements in technology that the construction industry has experienced have been heavily influenced by the most recent internet releases. This is commonly known as knowledge demonstration and permits significant improvements in terms of new methodologies. This strategy must permit interconnected functionality between differing software items, including those that are web-based and well thought out suggestions. In terms of the construction industry, software products need to include the ISO-10303 Standard Exchange of Product Data (STEP). Indeed, the IFC was made as a building model for use in the construction industry and using particular features from STEP. It has led to better building data by the application of semantic technology. The central ambition is to improve building information accessibility by producing information that can be managed electronically.

The most apt representation language is often thought to be OWL, particularly in terms of the visuals because it is efficient, familiar, and well supported. It must be acknowledged that this research does not consider offerings in other languages. However, it is still true that data relating to engineering methods does not feature a large variety of semantics and pragmatics [23].

The prototype designed must be able to develop some understanding whilst allowing individual input. Therefore,

judging the worth of the model is in many ways dependent on semantics, given that they allow for accurate results to be produced and the usefulness of the model to be assessed. Semantics are important because if the outputs are vague and open to different interpretations, this tends to be because do not have detailed semantics. The CAD programmes is an apt example, in that they provide developed drawing possibilities but do not have a human dimension (for instance, geometric shapes) because they lack semantic detail. The purpose behind BIM was to build models that made use of object-grounded images and to allow for a setting to be described semantically. In addition, BIM also allows for a resource of information to be included that construction industry experts can find to detect the precise product information they need. Many in the industry have been complimentary about BIM since it was set up as a way of dealing with long-running issues.

3. Methodological Foundation and Research Methods

All aspects of research cannot be considered in detail in a paper such as this and instead, the aim is to provide a precis of the methodology used as a prelude to considering the rational position on cost estimates and the author's assessment of the system that should be developed. An in-depth analysis of the logical issues around cost estimates, a semantic assessment of cost estimates and model development will not be items for discussion in this paper.

3.1. Overview of research methods

The research project is of 4 years duration and involves close analysis of design science methods with the aim of obtaining better standards of work in a digital setting. The project is in four stages; the pinpointing of issues, the putting forward of solutions, the creating of prototypes and the authentication of them. Many different research methodologies have been used, including a review of the relevant literature and professionals being interviewed as part of identifying present problems, with the results available in other papers. As part of the stage involving solution design, standards were reviewed, including data model standards as well as costing domain standards, in addition to interviews taking place to verify the procedures in relation to cost estimates. For the prototype development stage, because of technical restrictions, semantic web ontology will be used to epitomise domain knowledge. In addition, Prolog will be used as a specific reasoning mechanism that uses all the procedures and sections within the reasoned programming setting. The stage of validation involves the use of questionnaires and carrying out half-structured interviews of professional experts so that the results generated can be contrasted with those from the logic programming setting.

3.2. Philosophical stance of cost estimation

The solution espoused has been developed from a particular viewpoint, which is the knowledge aspect of cost estimation. It interprets cost estimation as a vibrant and collective procedure that is based on knowledge and develops as a result of modifications and fresh evidence. Cost estimates are taken as a type of semiosis, or sign-process tasks. The phrase 'semiosis' refers to a process that applies meaning to signs. This approach takes cost estimation as being illustrative of the sign-grounded building of experience models. The human thought process that is used to make decisions involves applying meaning (i.e. items) to signs. The way that the estimator interprets the sign is equivalent to the sway that the sign has.

In relation to the difficulties in determining and quantifying the cost item, illustrative examples are shown below:

Deduction: Rule: If the damp-proof is wider that 300mm, then measure is taken in metres squared;

Sign: Damp-proof >300mm

Object: Unit of measurement is square meter

This modern method of cost estimation suggests three crucial benefits to the procedure: 1) it brings in an authorised BIM-focused cost estimation structure, and includes human reasoning in the estimation process; 2) it improves the chance of information being offered within a context which means estimators are freed from the burden of prioritising particular information; and 3) it makes possible a knowledge-based model of cost estimation. This approach lays the groundwork for a more detailed examination of different kinds of analysis.

3.3. Development trends of computer system

Having closely assessed many different domains, it is the opinion of the authors that the pattern of future systems is going to be geared towards knowledge-based extensions of information systems. Moreover, using BIM technology offers a possible answer to the problem set out earlier through a specific and continuously evolving model during the lifetime of a project [24]. Nonetheless, the BIM model does not have a knowledge perspective at present, so its

operation is sub-standard.

In 2012, Hartmann (2012) introduced semiotics in assessing BIM systems. This was done with the intention of developing the communication competence of BIM. The semiotic structure concentrated on technical aspects [26] and, as shown in Liu (2000)'s semiotic ladder in 2000, particularly homed in on the IT stage. It is the author's considered view that the communication issues are because of something intrinsic in relation to the construction industry [28]. Given that the assessment focus on technological issues, it cannot thwart the particular issues arising in the construction business. The main needs are to do with social and structural issues, rather than technical expertise and, as such, how successful a business is in introducing information systems effectively depends on their preparation and planning as opposed to the technicality of the systems themselves [29].

The development of BIM solution must move towards a human-based solution [30]. Indeed, the National Institute of Buidling Sciences (2007) notes that BIM is a computer-generated replica of the actual form of a building. It is therefore a source of information for users to make informed choice in relation to the construction of the building. The authors studied a technological roadmap of BIM that Construction Excellence [31] designed and contend that for the ongoing development of the sector, this needs to be further developed, particularly in relation to AI extended BIM+. It would be helpful to have an AI system that searches through all of the information, spots patterns and unusual aspects, carries out many processes automatically and alerts users to issues that need extra focus. It would also be very useful if AI also pinpointed and clarified possible concerns and gave forecasts using data, so as to give support to the choices that managers make.

This dream of the development of computer systems requires at its heart that computers understand the workflow of professionals. Information has already been provided on the analysis of professional knowledge [32], and this paper instead concentrates on suggested solutions and authenticating results.

4. Proposed Solution

In assessing the context, many aspects to do with BIM-based cost estimation have been studied in detail. It has been suggested that modernised and developed processes could be used which are to do with the ontology used in the construction industry. However, at this point, no research has managed to merge the important aspects in one prototype. Despite many important pieces of research espousing the significance of a semantic underpinning in the domain [33,34], it is recognised that a synopsis is needed setting out all of the different views in relation to a system based on information, which includes compatibility (syntax), a description of pricing analysis (semantics), and precise information about the conditions surrounding the elements being assessed (pragmatics) [35].

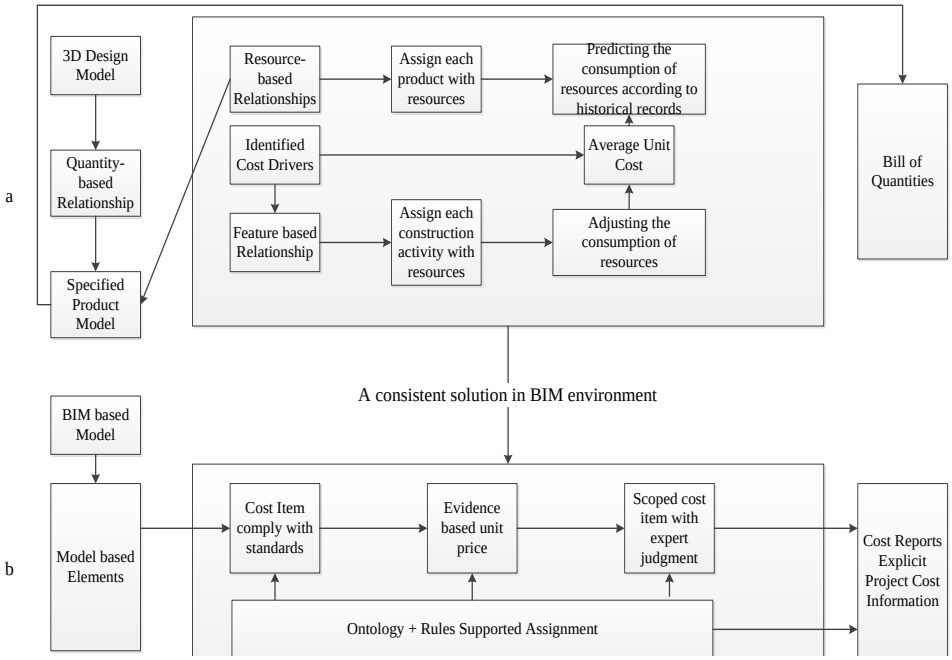

Figure 1 (a) The traditional method of cost estimation via BOQ; (b) The proposed knowledge-based System approach (KACE: Knowledge-based Automatic Cost Estimation)

Figure 1 illustrates the present system of quantity surveying. In designing particular product models for specific construction items, resource-based relationships and feature-based relationships need to be used in cost knowhow. Research indicates that as regards customary techniques of cost estimation, quantity-based relationships may be routinely given to the 3D design model [20].

The most widespread way of producing an accurate cost estimate within reasonable time and at reasonable cost is using the resource-based model. Moreover, activity-based costing can be viewed as an improvement to resource-based relations to ensure greater accuracy in results. Given that quantity-based relationships are straightforward and imprecise, it tends to be left to quantity surveyors to decide the way in which cost information should be amended to maintain equilibrium between the cost estimate and the scale of the project. To allocation an action to each product would require a very detailed model and significant exertion, even though the two models mentioned are still mainly dependent on manual input. To that end, they demonstrate the issues in relation to cost estimation. The first of these is quantity take-off, whereby despite the weighting and cost regulations being altered depending on national and business criteria, there is also significant variation between individuals on this. Secondly, the unit price varies hugely from one quantity surveyor to the next, and a major ambition is to design a constant and adaptable BIM solution [36].

Studying the new measurement systems [21] has allowed the author, in Figure 1b, to offer the notion of an agreed process of cost estimation that could be a reality in a digital environment. Ontology stands for the approach of being ledge focused in this research and the systems followed in this procedure can have an impact on new examples by using current mechanisms. The procedure pinpoints certain aspects and amends the unit cost rate accordingly. Thus, using knowledge from quantity surveyors is another issue that is central to this research exercise. The issue of current practice in terms of knowledge representation in BIM will be covered in the following section. In addition, the organisation issues in terms of using the knowledge from quantity surveyors will also be assessed.

As evidenced by a review of the literature, present BIM cost estimation is a disjointed knowledge process. The IFC model gives information about the building alongside the cost estimation process. The IDM confirms the information passed between the IFC model and the cost estimation and takes quantity off [37]. The IFD then provides the in-depth component knowledge that is within the IFC model but does not simplify the process of cost estimation. Additional improvements are needed from technological developments. A mixed methodology purports that a cost estimate is made using previous information and the project elements, and the cost estimate is then amended by experts to make it more insightful. However, there are variations in BIM-based cost estimations, which is unsatisfactory for industry experts. If knowledge is not integrated into the procedure of cost estimation, it is lost by the process and kept as a result of individual knowledge as to costs. In addition, the procedure can be further sub-divided to be more useful to the carrying out of professional activities by describing, identifying, selecting and amending data during the cost estimation process. Professional work cannot benefit unless a new approach for reviewing cost estimation that takes account of the human aspect, and provides a link between the IT programme and the human role is developed.

5. Prototype and Validation

To use the model so that it could be tested as part of the research, a form of the model was built to give cost estimation information. There were three stages in the development: (1) metadata was taken from code of practice documents, which are connected to cost estimates and laws of measurement [21]; (2) semantic details were recorded; and (3) the procedures were introduced.

Semantic assessment: to achieve the results of the assessment, the Order of Cost Estimation [38] and important processes in relation to cost estimation [39–43] have been assessed. 123 units of metadata have been created as a result.

Semantic data transfer: to achieve the results of the agenda, the semantic aspects used as part of the code of practice, as well as the IFC language, have been logged, as can be seen in Table 2.

Table 1 Semantic units mapping

Documents	Total IFC entity	Number of attributes	Number of relationships
Order of Cost Estimation	22	27	8
Bill of Quantities	42	59	22

Table 2 Result of comparison (Brick Wall)

Components	**Traditional method**						**Proposed method**
	A (4 years)	B (8 years)	C (2 years)	D (12 years)	E (6 years)	F (10 years)	
Cost Item Description*	A,B,C,D	A,B	A,B,C	A,B,C,D	A, B, C, D	A, B, C, D	A,B,C,D
Measured Quantity	12.46m^2	11.43m^2	12.46m^2	12.46 m^2	12.46 m^2	12.46 m^2	12.46m^2
Material Unit Cost	4.66$/$m^2$	49.72$/$m^2$	4.56$/$m^2$	6 $/$m^2$	4.66$/$m^2$	4.56$/$m^2$	4.56$/$m^2$
Labour Unit Cost	3$/$m^2$	33.71$/$m^2$	3.18$/$m^2$	4 $/$m^2$	3.17$/$m^2$	3.17$/$m^2$	3.17$/$m^2$
Adjust on Labour Unit Cost	0	0	Increase 20%	0	0	Decrease 20%	Decrease 30%
Scoped Labour Unit Cost	3$/$m^2$	33.71$/$m^2$	3.82$/$m^2$	4 $/$m^2$	3.17$/$m^2$	2.54$/$m^2$	2.22$/$m^2$
Total	$95.44	$953.60	$104.41	$124.46	$97.56	$88.47	$ 84.48

***Note: A: Material, B: Working Methods, C: Size, D: Location, E: Additions**

The results depicted in Table 3 are limited due to constraints of space, but they illustrate the contrast between results from specialist analysis and those of KACE with three different cost items. Expert A pointed out that the accuracy of brick wall estimates would be better if drawings of rebar and concrete beams were added as they could be utilised to strengthen the force of the wall. It would be a useful discussion to consider how these points could be used as part of the knowledge base or in the IFC model but it is beyond the scope of this research. Expert B noted there was insufficient information about tiles and extra quotations were needed. They also did not notice the boundary works had been included and, in the feedback, they agreed it needed to be included and the unit cost could be calculated from the information given. Expert C noted that the height of the brick wall might mean that productivity may reduce by 20% which would cause increased labour unit costs of 20%. Expert D gave the unit cost of brick based on his experience because of the shortage of drawings of rebar and concrete beams for brick walls.

From the different assessments given, KACE shows that expert analysis and knowledge of analytical cost estimation can be measured and leads to similar cost items as experts calculating it on their own. The variation between totals emphasises how vital it is to record and automate the procedure.

6. Limitations

Looking more broadly, the approach being suggested and its semantic, practical and standard and it would apply to other areas of construction, for instance, checking the energy performance of buildings, checking for collision, and BIM-based construction management. It is possible to use ontology and rules to computerise the knowledge works of professionals and to build reasoning models of the knowledge. Nevertheless, there is little agreement on how useful such mechanisms would be. In addition, it is unknown what the construction of social knowledge trends would look like, or how a special example of a knowledge model would vary from that ‘ideal’ state.

Looking ahead, research should aim at establishing a more in-depth appreciation of the BIM-based construction management. The discussion on the theory of working designs involves several related areas, from the role of artificial intelligence, to how procedures, models and data are seen. Nevertheless, applying this approach can make the gathering of information more straightforward and give it a context which will assist in introducing models for large amounts of data.

7. Conclusions

It believes that BIM is a procedure which uses object-focused models to design a building in addition to giving design information to all of those involved. The procedure involves using computerised data to take away the limitations of the construction sector. BIM methods should be assessed as a transporter of particular data that needs to be subject to further examination from construction experts. As noted by . Eastman et al. (2011), the primary focus should be on organisation rather than technical prowess.

The purpose behind the research was to design a method for automatic cost estimating based on BIM to offer an AI assisted professional workflow. A fresh method of using a KBS in a BIM setting can be put forward. Domain ontology can be engaged to encapsulate the semantics of the costing process and a business process modelling with norms can be used to measure the application logic (professional problem-solving procedure). In addition, an analysis on professional problem-solving methods and domain ontology in a reasoning technological setting can offer a connected approach to cost estimation.

Analysis supports the methodology of automatic cost estimation as being appropriate, and for BIM-based cost estimation to be extended to a knowledge viewpoint. The end target of the research is to put forward a philosophical viewpoint in terms of professional work, so that it is not only restricted to cost estimation but more broadly in the analytical procedure. To that end, another paper has been published that deals with healthcare analytics processes [45]. It should also be noted that no technical information has been given here because of the limitations of space, although it is the intention of the authors to publish detailed tech specification in Automation in Construction.

It needs to be observed that the addition of extra metadata and uses the clauses is at present done manually, and there is the potential for this to be done electronically. However, with increased confidence in automated systems, the expectation is that codes of practice will be carried out in a semantically targeted fashion which allow the links between items to have clarity. This amendment in how codes of practice are presented will mean that they are made in ways that allow them to be made automatically, with human comprehension being something that comes out of the system, rather than being involved in the input. This method of succeeding in having automated regulation checking procedures was supported by Beach et al. (2015).

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