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HEALTHCARE DESIGN ASSESSMENT USING SEMI-AUTOMATED APPROACHES FOR CODE CHECKING

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ABSTRACT

This paper reports initial research findings exploring the assessment of regulatory requirements in the healthcare design process, using different levels of automation – code checking. The methodological approach is Design Science Research, with an empirical study undertaken in close collaboration with an institution responsible for Primary Healthcare buildings in the UK. The main findings include understanding that the design of healthcare projects is intrinsically subjective, which is also reflected by the way regulations for healthcare buildings are developed. Thus, automated approaches for design assessment will only be suitable for the healthcare context if such approaches enable the consideration of requirements subjectivity. In fact, this consists of a change in the way subjectivity is considered in code checking research, which has traditionally been seen as problematic for the design assessment process, due to individual biases and potential misunderstandings. This research proposes that subjectivity in design assessment should be understood in terms of how its negative effects could be alleviated, but at the same time understanding it supports creativity and the uniqueness of human reasoning during the healthcare design process.

Keywords: *Healthcare design, Subjectivity, Requirements, Design assessment, Hybrid approaches*

1 INTRODUCTION

An extensive amount of information needs to be considered in healthcare design (KIVINIEMI; FISCHER, 2004; TZORTZOPOULOS et al., 2009; YU; SHEN; CHAN, 2010). Such information relates to the diverse needs of people and organisations involved in this type of projects, including healthcare specialists and associated technologies (CHELLAPPA, 2009). Information from multiple sources create requirements of different types, including abstract and concrete information (GUTMAN, 1982). An important part of these requirements are regulatory (MACIT İLAL; GÜNAYDIN, 2017; MARCHANT, 2016). Regulatory requirements can, in some cases, be qualitative and subjective, and therefore open to interpretation (NAWARI, 2012).

Within the UK healthcare design context, there are more than 100 healthcare related regulations, including (a) design guidance provided by the Department of Health; and (b) Building Regulations, which are mandatory for all buildings, provided by the Ministry of Housing, Communities & Local Government. This plethora of regulations can potentially disrupt the design process from both the design teams and regulatory organisations perspectives. The requirements contained in such regulations have an important function, describing minimum standards for assuring design compliance. This is fundamental so

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that healthcare facilities can provide functional and technological environments which contribute to successful health outcomes (TZORTZOPOULOS; CHAN; COOPER, 2005).

Past research has aimed to support the use of automated approaches for design assessment i.e. rule and code checking. These were mostly motivated by time consuming, inconsistent and prone to error outputs observed in the manual approaches (EASTMAN et al., 2009; NAWARI, 2013; MACIT İLAL; GÜNAYDIN, 2017; ZHANG; EL-GOHARY, 2017).

Despite representing an important move towards a more digital and BIM-enabled assessment/compliance process, these approaches have had only partial results in practice. The main reason reported by the literature for automated-based developments not alleviating the issues of design assessment is related to the subjectivity in requirements (NAWARI, 2012; DIMYADI; AMOR, 2013). Regulatory documents are developed using natural language, aiming to be read, interpreted and used by people (NAWARI, 2012). Therefore, they are indeterminate by nature because of their open-text elements, which hardly can be applied in automated scenarios (FENVES et al., 1995) due to: being context-dependent, requiring a considerable degree of interpretation to be judged (FENVES et al., 1995); and having an open-ended number of senses, which, in turn, implies in vagueness and ambiguity (NAWARI, 2012).

Even though this issue has been identified many years ago by e.g. Fenves et al. (1995), it is still reported in recent research efforts. Solihin and Eastman (2016) observed that using regulatory documents as an input for BIM-based rules is still a complex endeavour due to the language interpretation issue, which should be able to capture human knowledge in a formalised way to ensure completeness and precision.

The aim of this paper is to understand and discuss the potential use of hybrid, or semi-automated approaches, as a way to enable regulatory requirements subjectivity to be better understood and managed during design assessment for healthcare projects.

2 RESEARCH METHOD

This paper presents results of a preliminary research project adopting the Design Science Research approach. This approach supports solving practical problems in an effective and innovative way (HEVNER et al., 2004) and it enables advancements in the associated fields of knowledge (KASANEN; LUKKA; SIITONEN, 1993; LUKKA, 2003).

An empirical study is being undertaken in collaboration with an institution responsible for Primary Healthcare buildings across the UK. The main activities developed to date are: (i) understanding the context of Primary Healthcare buildings in the UK; and (ii) analysing one healthcare design regulation and classifying requirements embedded in it (HBN 11-01 – Facilities for Primary and Community Care Services, Department of Health, UK). Other future activities include: (a) analysis of a larger set of healthcare-related regulations; (b) explore the use of available software to support design assessment; and (c) explore the interaction between requirements management and design compliance to regulations. These activities will enable the development of an artefact, which is a method to support design assessment for healthcare projects.

3 RESULTS

Preliminary findings of the first phase of Design Science Research correspond to the initial understanding of the research problem and the development of the first version of

the artefact. This paper reports one element only, i.e. the analysis of one healthcare regulation in terms of type of requirements within it. This is a fundamental step towards automated rule checking application in practice (SOLIHIN; EASTMAN, 2016).

One of the main Primary Healthcare regulations in the UK (HBN 11-01) was analysed in terms of the amount of requirements embedded in the document and their associated subjectivity. The classification criteria used to analyse these requirements are presented in Table 1. It is important to acknowledge that the classification process undertaken can be subjective, so results must be analysed in a broad perspective.

Table 1 – Classification criteria used to analyse requirements

Criteria		Description
Logical Rule	Yes	The requirement either can or cannot be re-written according to a logical sentence structure, by defining both content and condition elements (SOLIMAN-JUNIOR; FORMOSO; TZORTZOPOULOS, 2019)
	No	
Abstraction	Subjective	The requirement depends on a certain degree of interpretation and reasoning to be incorporated in the design and assessed later in terms of compliance
	Objective	The requirement does not need of any degree of interpretation to be considered in the design process

Source: developed by the authors

From this analysis, 782 requirements were identified. From these:

- 52% are classified as subjective, i.e. they rely on some degree of human interpretation and reasoning to be verified in the design; and
- 48% are objective.

Examples of these requirement types are given in Table 2. The table also identify if the content of requirements can be translated into a logical rule.

- From the 408 subjective requirements identified, 16% could be transformed into a logic rule and used for automated checking, while 84% depend on human interactions;
- from the 374 objective requirements, 95% could be translated into logic rules, while 5% still should be verified with support from humans.

In fact, the analysis demonstrates some of the difficulties of using regulatory requirements as an input for complete automated design assessment, which has also been identified by previous research (NAWARI, 2012; DIMYADI; AMOR, 2013; SOLIMAN JUNIOR, 2018). These results should be understood in terms of how different degrees of automation should be explored in the development of design assessment systems, so that types of requirements could be properly considered and verified in the design solution.

In practice, this indicates a need for hybrid solutions, which could deal with requirements subjectivity in such a way as to not hamper the creativity of the design process – which is fundamental to improve design value. Such hybrid solutions would mix computer-based activities with human interactions – this concept is known in Lean theory and is defined as “automation with a human touch” (LIKER, 2004). It is essentially related to

(1) built-in quality; (2) mistake proofing; and (3) assuring that humans are free to perform value-adding work – people are in the centre of the system (LIKER, 2004).

Table 2 – Examples of Requirements from HBN 11-01

	Requirement	Logical Rule
Subjective	It is important that the accommodation is flexible and adaptable.	No
	Each suite should be large enough to maximise work efficiency but not so large that it becomes impersonal or difficult to navigate.	No
	Consulting/examination suites should be arranged possibly with an adjacent suite to enable patients to be referred on from their initial consultation to a specialist consulting/examination suite or treatment suite.	Yes
Objective	Clinical spaces (consulting rooms) for generic suites within primary and community care buildings should be 16 m^2.	Yes
	Public access to individual patient/client contact spaces will be controlled by staff.	No

Source: developed by the authors

There is another important result: automated approaches are used in practice more as a software-centred activity rather than a process-oriented task during building design (LEE et al., 2016). Instead of using the regulatory framework as a supporting tool to achieve better results during the healthcare design process, regulations are mostly used as a way to identify non-compliances. In fact, the use of hybrid approaches for design assessment could also contribute towards promoting a more iterative design process, enabling it as a supporting tool, rather than only a non-compliance identification mechanism. In summary, hybrid approaches for design assessment could be beneficial to the healthcare context because they allow: (i) appropriate consideration of requirements, which are subjective in nature; and at the same time (ii) enable shifting assessment to a continuous and iterative part of the overall design process.

4 CONCLUSIONS

Regulatory documents contain multiple types of requirements, with different levels of subjectivity. Thus, considering subjectivity as a fundamental element of the design assessment, especially for healthcare, appears to be key to develop systems that are capable of alleviating the issues identified from both manual and existing automated approaches, which in turn, can be potentially based on hybrid approaches.

In fact, results presented in this paper have an exploratory character and indicate a possible change in the way subjectivity is considered in design assessment. It has traditionally been seen as a harmful element of the design assessment process, due to individual biases and misunderstandings. Evidence presented in this paper demonstrates that new design assessment systems should address both objective and subjective requirements, which should be dealt differently.

Additionally, preliminary results indicate there are different degrees of subjectivity embedded in regulatory requirements. Future research should focus on mapping

subjectivity according to a structured classification, trying to determine which levels of automation are needed in hybrid approaches to assess subjective requirements in healthcare design.

REFERENCES

CHELLAPPA, J. R. BIM+ Healthcare: Utilization Of BIM In The Design Of A Primary Healthcare Project. **Doctoral diss., School of Architecture, University of Hawaii, Hawaii, USA**, 2009.

DIMYADI, J.; AMOR, R. Automated Building Code Compliance Checking – Where is it at? **Proceedings of CIB WBC 2013**, p. 172–185, 2013.

EASTMAN, C. et al. Automatic rule-based checking of building designs. **Automation in Construction**, v. 18, n. 8, p. 1011–1033, dez. 2009.

FENVES, S. J. et al. Computer representations of design standards and building codes: US perspective. **The International Journal of Construction Information Technology**, v. 3, n. 1, p. 13–34, 1995.

GUTMAN, J. A Means-End Chain Model Based on Consumer Categorization Processes. **Journal of Marketing**, v. 46, n. 2, p. 60–72, 1982.

HEVNER et al. Design Science in Information Systems Research. **MIS Quarterly**, v. 28, n. 1, p. 75, 2004.

KASANEN, E.; LUKKA, K.; SIITONEN, A. The Constructive Approach in Management Accounting Research. **Journal of Management Accounting Research**, v. 5, p. 243–264, 1993.

KIVINIEMI, A.; FISCHER, M. Requirements Management Interface to Building Product Models. p. 1–12, 2004.

LEE, H. et al. Translating building legislation into a computer-executable format for evaluating building permit requirements. **Automation in Construction**, v. 71, p. 49–61, 2016.

LIKER, J. K. **The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer**. Madison, WI: McGraw-Hill Education, 2004.

LUKKA, K. The constructive research approach. **Case study research in logistics. Publications of the Turku School of Economics and Business Administration, Series B**, v. 1, n. 2003, p. 83–101, 2003.

MACIT İLAL, S.; GÜNAYDIN, H. M. Computer representation of building codes for automated compliance checking. **Automation in Construction**, v. 82, n. June, p. 43–58, 2017.

MARCHANT, D. The design brief: Requirements and compliance. **Journal of Information Technology in Construction**, v. 21, n. November, p. 337–353, 2016.

NAWARI, N. O. The Challenge of Computerizing Building Codes in a BIM Environment. **Computing in Civil Engineering**, v. 1, p. 285–292, 2012.

NAWARI, N. O. SmartCodes and BIM. **Structures Congress 2013**, p. 928–937, 2013.

SOLIHIN, W.; EASTMAN, C. M. A knowledge representation approach in BIM rule requirement analysis using the conceptual graph. **Journal of Information Technology in Construction**, v. 21, n. March, p. 370–401, 2016.

SOLIMAN-JUNIOR, J.; FORMOSO, C. T.; TZORTZOPOULOS, P. A Semantic-based Framework for Automated Rule Checking in Healthcare Construction Projects. **Canadian Journal of Civil Engineering**, 2019.

SOLIMAN JUNIOR, J. **A Semantic-Based Framework for Regulatory Requirement and Rule Analysis of Healthcare Design**. Dissertação de Mestrado. Federal University of Rio Grande do Sul, 2018.

TZORTZOPOULOS, P. et al. The gaps between healthcare service and building design: a state of the art review. **Ambiente Construído**, v. 9, n. 2, p. 47–55, 2009.

TZORTZOPOULOS, P.; CHAN, P.; COOPER, R. **Requirements management in the design of primary healthcare facilities**. SIBRAGEC. **Anais**...2005

YU, A. T. W.; SHEN, G. Q. P.; CHAN, E. H. W. Managing employers' requirements in construction industry. **Facilities**, v. 28, n. 7/8, p. 371–382, maio 2010.

ZHANG, J.; EL-GOHARY, N. M. Semantic-Based Logic Representation and Reasoning for Automated Regulatory Compliance Checking. **Journal of Computing in Civil Engineering**, v. 31, n. 1, p. 04016037, 2017.

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