Recognising diversity of data management approaches towards lifecycle costing through personas

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RECOGNISING DIVERSITY OF DATA MANAGEMENT APPROACHES TOWARDS LIFECYCLE COSTING THROUGH PERSONAS

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SUMMARY: *Prompted by the increased interest in and strengthened incentives to apply lifecycle costing (LCC) in the Danish AECO industry, this study aims to improve our understanding of how practitioners may apply new technologies and tools in their design practices. By adopting user-centred design methods, this study explores the diversity of current and potential LCC users as users of technology in general with regard to their characteristics, aspirations and work processes towards data management. The research is based on a single case study analysis of a Danish architectural firm. Data are gathered through mixed methods, including quantitative surveys and qualitative observations and interviews. The findings reveal three user personas: the clip-boarder persona, who manually copies and pastes data from one application to another in order to perform calculations; the spreadsheet expert persona, who prefers to work with spreadsheet-based tools for importing and exporting data between tools; the programmer persona, who uses programming language for integrating data from one application to another. This research provides novel insights on users of technology that can advance integration of LCC in design practices and improve design of more useful adequate LCC tools.*

KEYWORDS: *User-centred design, personas, lifecycle costing (LCC), design practices, data management, data integration*

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1. INTRODUCTION

The Architecture, Engineering, Construction and Operations (AECO) industry is showing increased interest in sustainability focusing on environmental quality as well as social and long-term economic performance of buildings. In order to assess the economic performance, lifecycle costing (LCC) is frequently used as a decision-making methodology for evaluating alternative design solutions that have different cost profiles over time. LCC terms are defined by the international standard ISO15686 series on service life planning (ISO, 2017) followed by the European standard EN15643 series on sustainability of construction works (CEN, 2021).

Although the LCC concept appeared internationally in the mid-1960s (Ellram, 1993), the focus of the Danish AECO industry on LCC has been revitalized the past few years due to a number of new trends (Haugbølle and Raffnsøe, 2019). First, LCC is part of various certification schemes including DGNB certification, which was adopted in 2012 by Green Building Council Denmark for sustainable building and urban areas that include economic quality with a strong weight (DK -GBC, 2012). Second, due to new governmental regulations in 2013, LCC is now a mandatory requirement for public construction (Bygningsstyrelsen, 2017). Third, the European procurement directive of 2014 supports the use of total cost of ownership as an award criterion in competitive tendering (European Commision, 2014). Fourth, the new Danish building regulation of 2020 includes LCC as part of the new voluntary sustainability building class (Mortensen *et al.*, 2018). Moreover, the voluntary sustainability building class is expected to become a mandatory requirement for all large new buildings in 2023 (Bolig- og Planstyrelsen, 2021).

For managing LCC in practice, a range of guidelines, methodologies and tools exists (Caplehorn, 2012; Dhillon, 2010; Farr, 2011). As pointed out by Sørensen et al. (Sørensen *et al.*, 2016), the existing LCC tools are classified in three main categories with distinct characteristics and associated benefits and drawbacks: (1) spreadsheets (usually company-specific), (2) stand-alone applications, and (3) web services. The Danish AECO industry typically performs LCC calculations based on a combination of three tools (Saridaki *et al.*, 2019): (1) Sigma Estimates: a 5D BIM cost estimation tool (Sigma Estimates, 2003); (2) LCCbyg: a Danish application for LCC analysis that also support DGNB calculations (LCCbyg, 2022); and (3) internally developed spreadsheets.

Despite the availability of various methodologies and tools, there are still significant challenges in applying LCC in work practices. Several studies have investigated the barriers of a limited adoption and implementation of LCC. These include: insufficient understanding of LCC definitions and methods (Gluch and Baumann, 2004), limited tool awareness (Olsson *et al.*, 2015), lack of usable tools (Goh and Sun, 2016; Olubodun *et al.*, 2010), lack of reliable data (Fu *et al.*, 2007; Oduyemi *et al.*, 2014), lack of formal guidelines (Kehily and Underwood, 2017), complexity of calculations (Fu *et al.*, 2007), insufficient methodology for data management and poor data collection and storage (Fu *et al.*, 2007; Saridaki *et al.*, 2019), and limited communication and collaboration between the LCC practitioners and the design team (Saridaki and Haugbølle, 2019).

Despite the technological opportunities offered by Building Information Modelling (BIM) in relation to different approaches of data integration (NBS, 2018; Singh *et al.*, 2009) and LCC (Fazeli *et al.* 2022; Liu *et al.*, 2015; Lu *et al.*, 2014; Miettinen and Paavola, 2014; Motalebi *et al.*, 2022; Saridaki *et al.*, 2019; Xu *et al.*, 2014), the current strategies of the AECO industry towards data integration do not enable the design of fruitful interventions towards LCC adoption. Hence, this study aims to improve our understanding of how LCC users apply digital technologies in their practices as a novel action for stimulating LCC integration in the AECO industry and for formulating requirements to new relevant tools and processes for practitioners. Rather than focusing on the limited adoption of LCC, this study adopts a positive agenda aiming to improve our understanding of how people work with LCC in real work practices. Adopting a generic user-centred design approach that focuses on how people work with technology in general, this study aims to provide novel information about the diversity of practitioners in the AECO industry by answering the research question: "How do practitioners of the AECO industry apply different LCC technologies and tools in their practices?". This knowledge will be valuable for both improving LCC integration in design practices and designing more useful LCC tools. Hence, the research objectives of this study are:

- to understand the diversity of LCC users in the AECO industry;
- to categorize their distinct core characteristics, work practices and data management approaches;
- to summarize the diversity of LCC users in distinct personas.

2. METHODOLOGY

The present research relies upon a user-centred design approach and more specifically the concept of personas. The data in this research were collected by conducting a systematic literature review as well as a case study analysis in a Danish architectural firm. In the following subsections, the literature review as well as both the theoretical background on user-centred design and the practical methodology along with the data collection methods are described.

2.1 Literature review

The research began with a systematic literature review following step by step the methodology proposed by *Okoli* (2015). The purpose of the review was to map the current practices and identify challenges regarding LCC and data management, as well as to understand the benefits of applying UCD methods and how they may contribute to a better understanding of practices. Thereby, the research contained the following aspects: (1) lifecycle costing (LCC), application and barriers; (2) data management, data approaches; (3) user-centred design (UCD) and personas, benefits and application. The authors searched for relevant literature on Google Scholar and online databases and gathered several studies concerning the three above-mentioned subjects that were assessed for their quality and relevance. The results of the literature review were used to build the introduction of this research study and set the research question and research objectives. Moreover, the literature was beneficial for selecting the methodological approach towards the construction of users' personas that is presented in the following sections.

2.2 Theoretical background: User-centred design and personas

User-centred design (UCD) is a human-computer interaction philosophy (LeRouge *et al.*, 2013) that focuses on developing systems based on users' requirements instead of technical requirements (Junior and Filgueiras, 2005). The UCD approach originates with Donald Norman, who used the term to describe design processes that are influenced by the end-users (Norman and Draper, 1986). The key aspect in UCD is to enable usability and usefulness in products and services through the active involvement of users in the design processes (Ji-Ye Mao *et al.*, 2005). Various methods are used in UCD such as users' interviews and surveys, focus group, participatory design, usability testing, ethnographic design and user scenarios with and without personas (Grudin and Pruitt, 2002).

The concept of personas was introduced by Alan Cooper in 1999 (Cooper, 1999) and is increasingly used for software design, product development and marketing purposes. There are several examples of using personas in both practice and academia, for instance for developing or evaluating systems and tools (Dantin, 2005; Gulliksen *et al.*, 2003; Hjalmarsson *et al.*, 2015; Lindgren *et al.*, 2007; Llerena *et al.*, 2016; Sakao and Shimomura, 2007); for educational purposes (Almahri *et al.*, 2019; Dotan *et al.*, 2009); for product design (Guo *et al.*, 2011; Wilkinson and De Angeli, 2014); and for health informatics research (Holden *et al.*, 2017; Wärnestål *et al.*, 2017). Moreover, personas have been used as a design tool in a number of world-leading firms in various business sectors (Miaskiewicz and Kozar, 2011; Pruitt and Grudin, 2003).

Although personas are not widely used in the AECO industry, there are a few examples that personas have been a useful tool contributing to increase the understanding of current practices and finding areas of improvement. Personas have been used e.g. to identify potential areas for BIM application in the FM stage (Becerik-Gerber *et al.*, 2012); for optimising sustainable solutions in buildings design towards circular economy (De los Rios and Charnley, 2017); on understanding users' needs, motivating human-centred design instead of cost-driven or technology-centred design e.g. to the design of smart-homes (Agee *et al.*, 2021); and for evaluating processes and tools e.g. a framework for supporting constructability analysis meetings with immersive VR-based collaborative 4D simulation (Boton, 2018).

Personas represent concrete group of users that designers are willing to design for (Floyd *et al.*, 2008), and it is a methodology that helps designers to make user-centred design possible (Pruitt and Adlin, 2006). Personas are hypothetical archetypes that represent groups of people that share similar characteristics, motivations and needs (Pruitt and Adlin, 2006; Turner and Turner, 2011). Although they are fictional, they represent real people through the design process. However, they are not made-up, but they are discovered with precision and rigor through contact with real users (Junior and Filgueiras, 2005). Usually, one to seven personas are built to support a project (Marshall *et al.*, 2015). They are used to communicate user requirements to designers (Kantola *et al.*, 2007) and

drive decision-making processes about interaction design and characteristics of a product (Goodwin, 2001) facilitating useful and usable design (Floyd *et al.*, 2008; Grudin and Pruitt, 2002). In order to make personas more realistic, memorable and engaging, designers add to them fictional characteristics like names, images and personal details (Cooper *et al.*, 2014; Pruitt and Adlin, 2006; Pruitt and Grudin, 2003). Creation of personas is the first step of a design lifecycle (Turner and Turner, 2011) and helps organizations to be more user-focused (Pruitt and Adlin, 2006).

There are several benefits of using personas compared to traditional research methods (Chapman and Milham, 2006; Miaskiewicz and Kozar, 2011) including:

- Personas evoke design teams to think about users and their goals as well as to integrate user needs into the system leading to more user-friendly design (Chapman and Milham, 2006; Cooper, 1999; Grudin and Pruitt, 2002; LeRouge *et al.*, 2013; Long, 2009).
- Personas facilitate effective communication between designers and users since they create a common language (Cooper, 1999; Pruitt and Grudin, 2003).
- Personas increase engagement and effective communication among the design team and can be used as a useful reference throughout the entire design process (Cooper *et al.*, 2014; Grudin and Pruitt, 2002; LeRouge *et al.*, 2013; Stickdorn *et al.*, 2018).
- Personas guide the decision-making process and help design teams to address problems that arise when a full range of user data is presented (Chapman and Milham, 2006; LeRouge *et al.*, 2013; Long, 2009).
- Personas make knowledge about users and their needs explicit and help designer to make explicit assumptions about the users (Grudin and Pruitt, 2002).
- Personas enable more effective and faster design, since designers are able to prioritize features and make decisions based on a small group of users (Wodtke and Govella, 2009).
- Personas build empathy for users among designers (Pruitt and Adlin, 2006).

2.3 Practical methodology and data collection methods

Research activities and collection of research data is a one of the core tools in UCD. In order to build personas, research data are made of facts from users, which are collected, synthesized, interpreted and analysed in order to identify recurring patterns within users (Junior and Filgueiras, 2005). There are multiple sources for data collection to support personas' creation such as interviews, observations, surveys, dramaturgical reading methods, ethnographic studies, web analytics and contextual inquiries (Dayton, 2003; Junior and Filgueiras, 2005; Kantola *et al.*, 2007).In this study, a single case study analysis was performed in a Danish architectural firm, which is located in Copenhagen, Denmark and is a frontrunner in sustainable design, including LCC. The case company applies LCC in various projects, and it is selected as the case of the analysis since it employs constructing architects, architects, and engineers.

The research process followed the eight principle steps of constructing personas proposed by Cooper et al. (Cooper *et al.*, 2014), which are illustrated in Fig. 1.

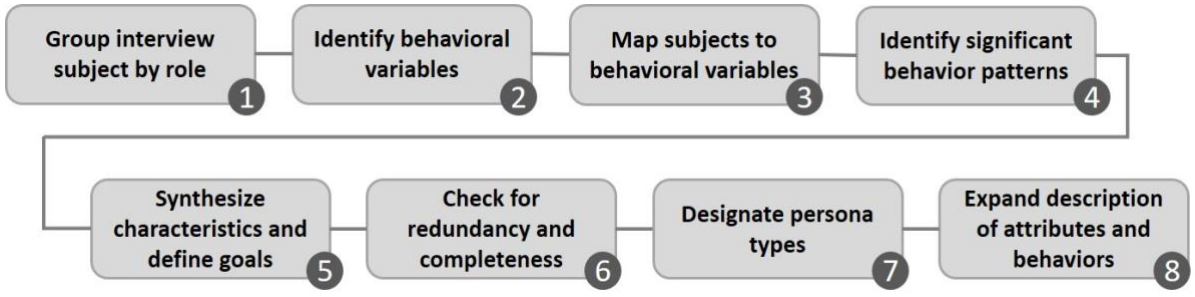

FIG. 1: Eight principle steps for constructing personas (Adapted after Cooper et al. 2014).

Throughout the entire process, mixed methods of data collection were used in order to triangulate the understanding of users and continuously validate, support and enhance the results, including different data collection strategies, both qualitative and quantitative and sources such as interviews, questionnaire survey and observations in the company (Denzin and Lincoln, 1994; Yin, 2014). The data-collection methods that were used in each step of this process are presented in Table 1.

TABLE 1: Data collection methods used in each of the eight steps of constructing persona process.

Step of constructing personas	**Data Collection Methods**
1: Grouping interview subject by role	Literature review on LCC application in practice Stakeholder analysis Selection of case study Case study: semi-structured interviews, observations, meetings and seminars
2: Identifying behavioural variables	Case study: observations on case subjects' behaviours for identifying behavioural variables
3: Mapping case subjects	Case study: online survey via Google Forms, 20 questions corresponding to the behavioural variables, 48 responses (out of 60)
4: Identifying significant behavioural patterns	Analysis of surveys results Case study: direct observations to support the results
5: Synthesise characteristics and define goals	Revision of qualitative and quantitative data Case study: additional observations and goal-oriented interviews
6: Check for completeness and redundancy	Revision of data collected in all previous steps Case study: five days on observations and interviews of the case subjects Two meetings with case company's representatives
7: Designate personas	Case study: internal meetings with case company's representatives
8: Expand the description of attributes and behaviours	Further analysis of already gathered results

3. FINDINGS: CONSTRUCTING PERSONAS

In the following sections, the findings are presented throughout the process of constructing personas by following the eight principles' framework of Fig. 1.

3.1 Step 1: Grouping interview subjects by role

In Step 1, the authors conducted a preliminary analysis, a literature review, and a stakeholder analysis in order to recognize and group the different stakeholders of LCC by role. The analysis resulted in the identification of three main roles of LCC stakeholders in the AECO industry, which are:

1) providers, including all stakeholders that provide software or the required data for an LCC analysis;
2) users, including all stakeholders that use an LCC tool to perform an LCC analysis, like architects, engineers, consultants and facility managers; and
3) clients, including all stakeholders that make decisions based on the results of the LCC analysis, like building clients.

The stakeholders have different interest and influence on the adoption of LCC in their work practices. LCC providers, for instance, have increased interest in LCC adoption since the increased use of LCC will be beneficial for their businesses and earnings, however, they do not have enough power to influence the LCC adoption. On the other hand, building clients have high power on increasing the use of LCC in the AECO industry. However, they usually consider only short-term costs for making investment decisions (Gluch and Baumann, 2004). On the contrary, LCC users have higher interest and higher influence on LCC adoption than providers and clients respectively. LCC users are interested in using LCC since it contributes to their businesses and earnings, and it contributes to sustainable design and constructions. Moreover, they can influence the adoption of LCC by providing services to their clients that indicate the benefits of using LCC in order to make decisions in the project. As a result of the analysis, it was decided to narrow the research focus to current and potential LCC users since they are important stakeholders in terms of both interest and influence on LCC application in work practices.

After a series of meetings and seminars, a case company (the architectural office mentioned previously) employing current and potential LCC users was selected as the case study. The authors analysed the internal workflow of the architectural office as case study and identified factors and conditions that support or prevent the application of LCC in design practices.

3.2 Step 2: Identifying behavioural variables

After the identification of the case study, the second step of the process included observation of behaviours of the case subjects and identification of behavioural variables. According to Cooper et al. (2014), demographic variables such as gender, age or demographic location can also affect behaviour; however, the identification of behavioural variables is more useful for creating effective archetypes. The number of behavioural variables varies from project to project; however, it usually ranges from 15 to 30 variables per role (Cooper *et al.*, 2014).

Through the case study analysis, six categories of behavioural variables were identified (A-F) and presented in the first column of Table 2. Under each category, two to five behavioural variables were selected for examination.

TABLE 2: Data collection methods used in each of the eight steps of constructing persona process.

Categories	No	Variables in each category
A. Aptitude	1	Education
	2	Education level
	3	Role in the company
B. Personality	4	Introvert vs extrovert
	5	Judging vs perceiving
	6	Feeling vs thinking
	7	Resistant vs adaptive
C. Skills	8	Familiarity with technology and programs
	9	Programming skills
	10	Familiarity with spreadsheets
	11	Familiarity with graphical applications
	12	Familiarity with CAD applications
D. Activities	13	Use of software in general
	14	Use of software in work practices
	15	Frequency of using software
E. Attitude	16	Evaluation of software in terms of usability
	17	Challenges of using those software
F. Motivation	18	Expectation of improvement in software
	19	Need of additional features or software
	20	Goals by using different software

In the category of aptitude, three variables were identified namely users' education, level of education and role in the company, which indicate users' level of knowledge and ability to learn. Under the personality category, four variables were selected that reveal the curiosity of users on learning and developing skills. Those variables indicate how introvert or extrovert, how judging or perceiving, how feeling or thinking and how resistant or adaptive the users are. Under the category of skills, five variables are used to evaluate users' skills on technology and programs as well as to understand their familiarity with commonly used applications such as office applications, graphical applications (that processing via pixels array) and CAD applications. In the activities' category, three variables were used to understand the activities of users in terms of frequency and volume. In the attitude category, two variables were selected, the one to understand what users think about those activities and the other to identify users' challenges. Lastly, under the motivation category, three variables were set to describe users' expectations, needs and goals.

3.3 Step 3: Mapping case subjects

In step 3, the case subjects were mapped against each of the behavioural variables that was identified in the previous step. Mapping of the case subjects is a significant procedure for identifying the placement of each subject in relation to the others (Cooper *et al.*, 2014). Here, the precision of the position of the case subjects is less important than the relative position between them. However, due to the large sample of this analysis, the relativity of positions of case subjects was not distinguished for each one of the case subjects; instead, it was evaluated in a six-levels scale. For instance, for mapping the case subjects against the fourth variable of Table 2 (Category: Personality, Variable 4: introvert or extrovert) a six-level linear scale was used, and the case subjects were placed relatively along this scale. Thus, a case subject that is placed in level 3 of the scale is more introvert than the case subjects that are placed in level 4. However, there is no further categorization between the case subjects that belong to the same level.

The results were carefully checked and assessed by the researchers since in many variables, especially in categories B and C, the results are highly subjective since the case subjects evaluate themselves. Hence, before mapping the case subjects against those variables, the researchers evaluated and supplemented the results based on the finding of the qualitative analysis that was performed in the earlier step, and additional observations in the case study. The results of mapping the case subjects are presented below.

Regarding the aptitude variable, the results indicate that the education of the case subjects is mainly on architecture, since 90% of the case subjects are architects. The level of education in the case company is high, since 64% of the case subjects have either PhD or master's degree. In addition, most of the case subjects work as design architects or project manager with percentage of 35% and 33% respectively. The results are presented in Table 3.

TABLE 3: Mapping case subjects against behavioural variables of aptitude category.

Aptitude Category (The result are based on the responses of 48 participants)		
Education	Architects, including landscape architects Construction managers and engineers	43 (90%) 5 (10%)
Education Level	PhD degree Master of Art/Master of Architecture, or similar Diploma Intern/student	2 (4%) 29 (60%) 9 (19%) 8 (17%)
Role/Task in the company	Design architect Project manager Urban planner Communication, R&D Other	17 (35%) 16 (33%) 4 (8%) 3 (6%) 8 (18%)

By mapping the case subjects against the behavioural variables of the personality category, it was observed that there are both introvert and extrovert participants. However, there are more perceiving, thinking and adaptive case subjects compared to judging, feeling and resistant, respectively (Table 4). More specifically, in total 69% of the case subjects are placed in levels 4, 5 and 6, meaning that they are more perceiving compared to the rest of the 31% case subjects that are placed in levels 2 and 3 of the scale. Moreover, most of the participants are thinking with a percentage of 27% and 36% to be placed in levels 4 and 5 of the scale, respectively. In addition, it was observed that 12% of participants are highly adaptive, while none of them is highly resistant. However, 18% of the case subjects are placed in levels 2 and 3, and 69% are placed in level 4 and 5, indicating that the majority of the participants are relative adaptive to new technologies and practices.

TABLE 4: Mapping case subjects against the behavioural variables of personality category.

Personality category (The result are based on the responses of 48 participants)							
	1	2	3	4	5	6	
Introvert	0 (0%)	13 (27%)	11 (23%)	8 (17%)	15 (32%)	1 (2%)	Extrovert
Judging	0 (0%)	4 (8%)	11 (23)%	15 (31%)	16 (33%)	2 (5%)	Perceiving
Feeling	0 (0%)	3 (6%)	15 (31%)	13 (27%)	17 (36%)	0 (0%)	Thinking
Resistant	0 (0%)	3 (6%)	6 (12%)	12 (25%)	21 (44%)	6 (12%)	Adaptive

Regarding the results of mapping the case subjects against the behavioural variable in the category of skills, it is remarked that most of the participants are familiar with technology and programs, and there is a high level of knowledge on using spreadsheets, graphical applications and CAD applications in the case company. Counter wise, only a small percentage of participants have high programming skills (Table 5). In particular, in total 54% of the case subjects are very familiar with technology and are placed in level 5 and 6 of the scale, while in total 42% are placed on levels 3 and 4, and only 4% on level 2. Regarding the familiarity with spreadsheet applications, graphical application, and CAD applications, in total 34%, 63% and 59% are placed in sum of level 5 and 6, respectively. By contrast, only 4% of the case subjects are completely unfamiliar with graphical applications and are placed in level 1 of the scale. In addition, a high percentage of the case subjects have low or none programming skills, in contrast to 2% that have high programming skills. However, half of the case subjects (49%) have medium programming skills and are placed in level 3 and 4 of the scale.

TABLE 5: Mapping case subjects against the behavioural variables of skill category.

Skills category (The result are based on the responses of 48 participants)						
(From 1: low to 6: high)	1	2	3	4	5	6
Familiarity with technology and programs	0 (0%)	2 (4%)	6 (12%)	14 (30%)	20 (42%)	6 (12%)
Familiarity with spreadsheets	0 (0%)	8 (17%)	8 (17%)	15 (32%)	9 (19%)	7 (15%)
Familiarity with graphical applications	2 (4%)	4 (8 %)	3 (6 %)	9 (19%)	19 (40%)	11 (23%)
Familiarity with CAD application	0 (0%)	3 (6%)	6 (12%)	11 (23%)	15 (32%)	13 (27%)
Evaluation of programming skills	11 (23%)	7 (14%)	5 (11%)	18 (38%)	6 (12%)	1 (2%)

Regarding the activities of the case subjects, the results of the case study analysis indicated that 85% of the case subjects use word processing or spreadsheet applications in their work processes. Likewise, CAD and BIM applications are used by 83% and 60% of the participants, respectively, while only 29% work with cost calculation tool. However, 50% of the case subjects use CAD applications weekly on their work practices, while 35% use BIM applications and spreadsheets, 33% use word processing applications and 2% use cost calculation software. The results are illustrated in Table 6.

TABLE 6: Mapping case subjects against the behavioural variable of the activities' category.

Activities category (The result are based on the responses of 48 participants)		
Use of software in work practices	In general	Weekly
Word processing applications	41 (85%)	16 (33%)
Spreadsheet applications	41 (85%)	17 (35%)
CAD applications	40 (83%)	24 (50%)
BIM applications	29 (60%)	17 (35%)
Cost calculation applications	14 (29%)	1 (2%)

Mapping the case subjects against the attitude category of behavioural variable, the results indicate that the majority of word processing applications' users and CAD users believe that word processing and CAD applications are either very easy or easy to use tools, in contrast to BIM users who believe that BIM applications are very hard to use. Regarding spreadsheet applications and cost calculation applications, 35% and 61 % of the users stated that it is normal to use spreadsheets and cost calculation tools respectively, while 38% and 21% stated that it is hard to use spreadsheets and cost calculation applications respectively. The results are presented on Fig. 2. All case subjects, however, face different challenges regarding the use of software. Through the case study analysis, it was observed that those challenges are mainly related to the lack of interoperability between software, default settings, different keyboard shortcuts between software, even between software of the same vendor, crashes of software and the need for different software in different phases of the project.

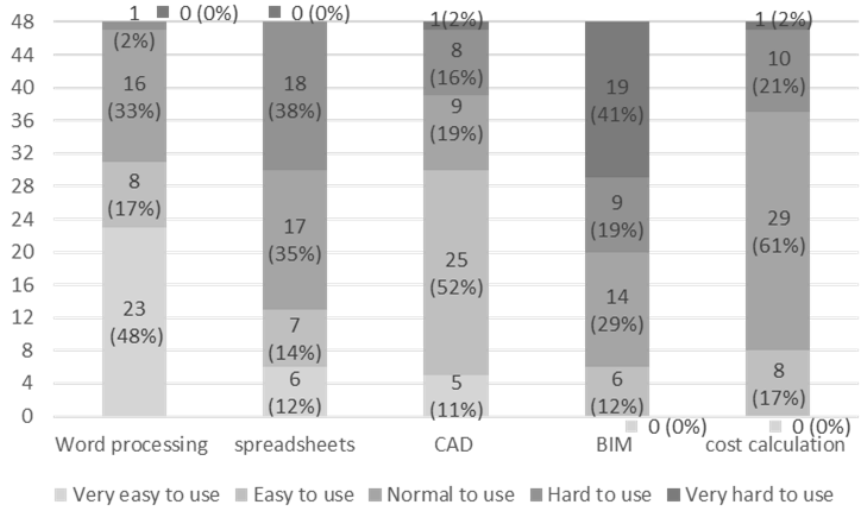

FIG 2: Mapping case subjects against the behavioural variable of the attitude category.

Regarding the results of the motivation category, the case subjects are willing to reduce time by using the software more effectively, reduce effort and manual work to produce results and increase compatibility between software. As it is indicated in Fig.3, for improving software usage, the majority of the case subjects would like to have simpler software that are compatible with other application and offer automate features. Moreover, they would like to have more templates and standards to guide them by the use of new software.

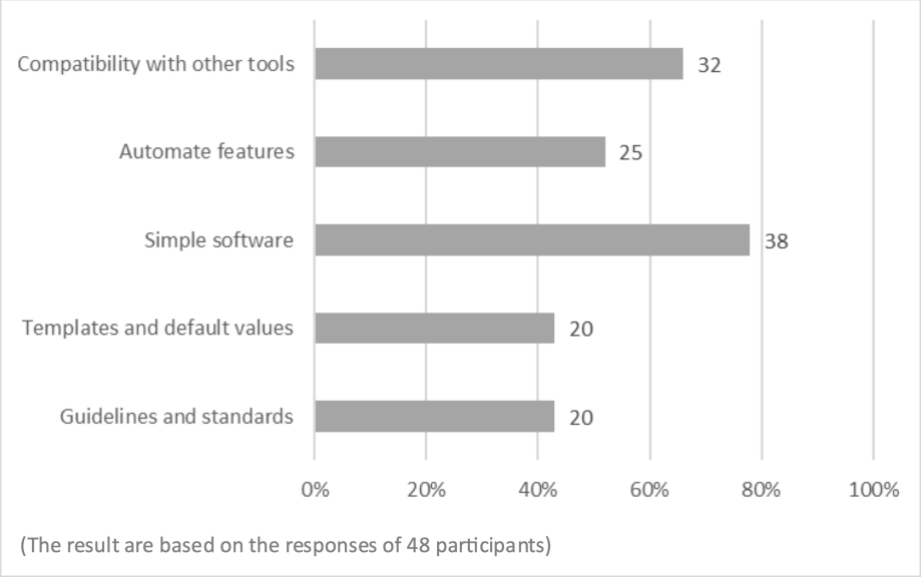

FIG 3: Mapping case subjects against the behavioural variable of the motivation category.

3.4 Step 4: Identifying significant behavioural patterns

After mapping the case subjects against the behavioural variables, the next step of constructing personas is the identification of significant behavioural patterns. Significant behavioural patterns are considered when a set of six to eight variables is observed to be followed by a group of case subjects (Cooper *et al.*, 2014). A pattern should present a causative and logical connection and not just a random correlation in order to be valid.

For identifying significant behavioural patterns, the authors analysed the correlation of the results of the previous step. Through the preliminary research and the initial steps of the process, several hypotheses for different patterns were assumed based on the qualitative analysis of the case study that was checked for validity or rejection. The analysis indicated three significant behavioural patterns, which form the basis of the personas.

The first pattern indicates a group of case subjects that are architects, more feeling than thinking, have low programming skills and work with word processing applications and CAD applications in their work practices. They face challenges of extensive manual work, and they need to save time and reduce effort. The second pattern shows a group of architects that are more introvert and less extrovert, have medium programming skills and work with BIM applications and spreadsheets. They challenge compatibility of software, and they would like to minimize errors and have easy procedures. The third pattern indicates that some of the participants with engineering skills are more judging than perceiving, however, more adaptive to new technologies. They have high programming skills and work with BIM applications. They would like to have interoperability between software in order to enable automation and reduce time spending on transferring data between software (Table 7).

TABLE 7: Significant behavioural patterns of the case subjects.

Pattern 1	**Pattern 2**	**Pattern 3**
Architect	Architect	Engineering skills
Less thinking - more feeling	More introvert - less extrovert	More judging - less perceiving
Low programming skills	Medium programming skills	Less resistant - more adaptive
Use of word processing applications	Use of spreadsheets	High programming skills
Use of CAD applications	Use of BIM applications	Use of BIM applications
Challenge: Manual work	Challenges: Compatibility	Challenges: Interoperability
Goal: Save time. Reduce effort	Goal: Minimise errors. Easy procedures	Goals: Automation. Reduce time

3.5 Step 5: Synthesize characteristics and define goals

After the identification of significant behavioural patterns, the next step of synthesizing characteristics and defining goals was performed. Personas goals were defined through their behaviours by observing typical usage of tools and work practices. Therefore, in this step, each significant pattern of the previous step 4 was synthesized with details regarding behaviours, emotions associated with the behaviour, pain-points, skills and experiences related to the behaviour, etc. as it is suggested by Cooper et al. (Cooper *et al.*, 2014). Moreover, at this step the most significant fictional details were also added: the persona's first and last name. In this study, for generating random names for personas, the authors used a random-name-generator application. However, since this research adopts a more generic perspective, it was decided to omit the personas' names in order to avoid nationality bias etc. Counter wise, demographic information such as age and job title were added, since this information is significant to visualize personas (as it suggested by Cooper et al. (2014)).

The analysis resulted in additional bullet points describing behavioural characteristics of the three personas (Table 8). Persona 1 presents traditional behaviours of working, and he is well-known for his office skills. He manually copies and pastes data from one application to another, and he usually asks for help from his colleagues to perform calculations. His goal is to finish task on time, and he thinks it will be easier if the software were simpler. Persona 2 uses spreadsheets for her calculations. She prefers to perform LCC in spreadsheets because she is restricted by the default setting of several applications. However, she is challenged by several errors that ends up with a lot of manual work. Her goal is to have more structured data. Persona 3 likes to use programming languages in order to automate the calculation processes and avoid repetition of tasks. He is flexible on using different tools and methods; however, he is also critical about them.

TABLE 8: Synthesized significant behavioural patterns with details for users.

	Pattern 1	**Pattern 2**	**Pattern 3**
Age	46 years old	37 years old	31 years old
Characteristics	Traditional character Manually copy-pastes data Need assistance from his/her colleagues	Independent – no need for assistance Calculations in spreadsheets	Technology enthusiast Develops scripts to minimize manual work
Pains	Unsure about data input Manual work Time-consuming tasks	Manual work to correct and structure data in spreadsheets Restricted by the default settings	Unstructured data Software crashes
Gains	Finish tasks on time Minimize errors	Better workflow Reduce time	Automate processes Reduce time

3.6 Step 6: Check for completeness and redundancy

After the identification of personas characteristics and goals, personas were checked for completeness and redundancy. In this step, it is important to ensure that personas sufficiently represent the diversity of behaviours and needs in the study as well as to map any important gaps that need to be filled. Therefore, the authors revised all material that was collected in previous steps and performed additional observation, few informal interviews, and meetings with company's representatives throughout a one month period. The analysis confirmed the representation of the identified personas; however, it resulted in identifying some missing information and filling in important gaps about the three personas. For instance, with regard to LCC it was observed that Persona 1 usually works in early design stages of projects, while Persona 2 has been involved in using LCC for DGNB certifications at the late design stages.

3.7 Step 7: Designate personas

By this step, personas' characteristics were completed and validated, and personas already feel like real people. Next step of the process for constructing personas was to designate persona types. According to Cooper et al. (2014), this is a key step since the research data are turning into a powerful set of design tools. Personas are prioritized, and the design target becomes explicit.

There are six types of personas namely primary, secondary, supplemental, customer, served and negative (Cooper *et al.*, 2014). Primary persona is the main target of design and the designers' focus on satisfying its goals. Usually there is only one primary persona per design interface. A secondary persona is mostly satisfying with primary personas interface; however, it has specific additional needs that can be accommodated without upsetting the product's ability to serve the primary persona.

In this study, however, the authors did not prioritize between the three personas that have been identified, since all three personas are equally important for analysing and understanding different types of LCC users.

3.8 Step 8: Expand the description of attributes and behaviours

In the last step, the description of attributes and behaviours of personas were expanded, and personas' narrative and photo were added. Personas' narrative should be short and quick, and it should introduce the persona in terms of significant characteristics and goals. Photos make personas feel more real, and it is helpful for increasing understanding and engagement (Pruitt and Adlin, 2006).

In Fig. 4, 5 and 6, the profiles of the three personas that have been uncovered through this study are presented. In those personas' profiles, the different characteristics of each persona are indicated along with aspiration and work processes.

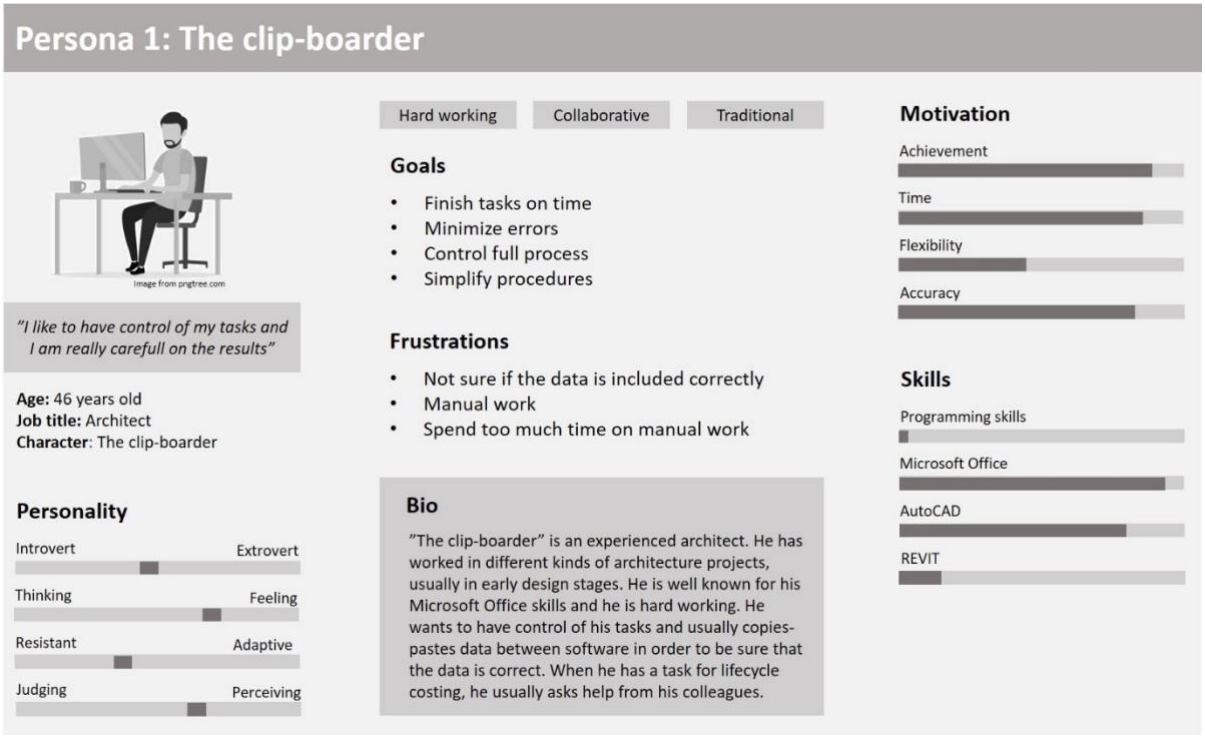

FIG. 4: Full profile of persona 1, the clip-boarder.

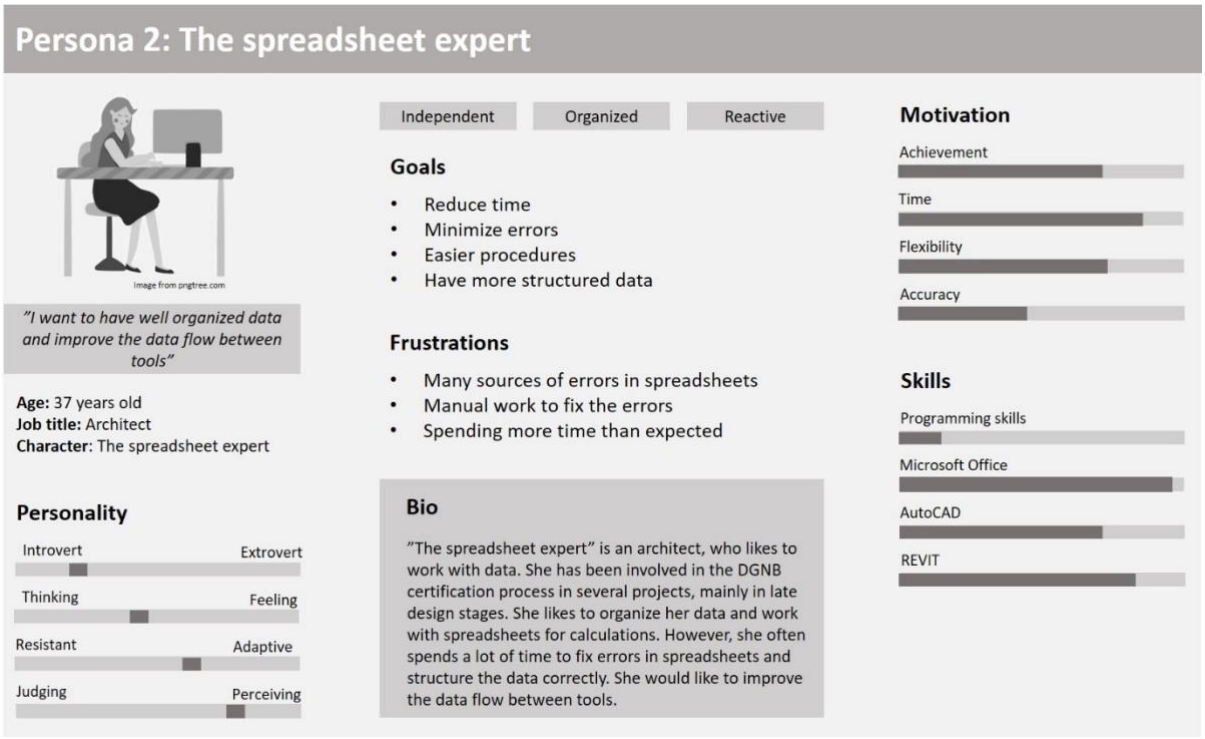

FIG. 5: Full profile of persona 2, the spreadsheet expert.

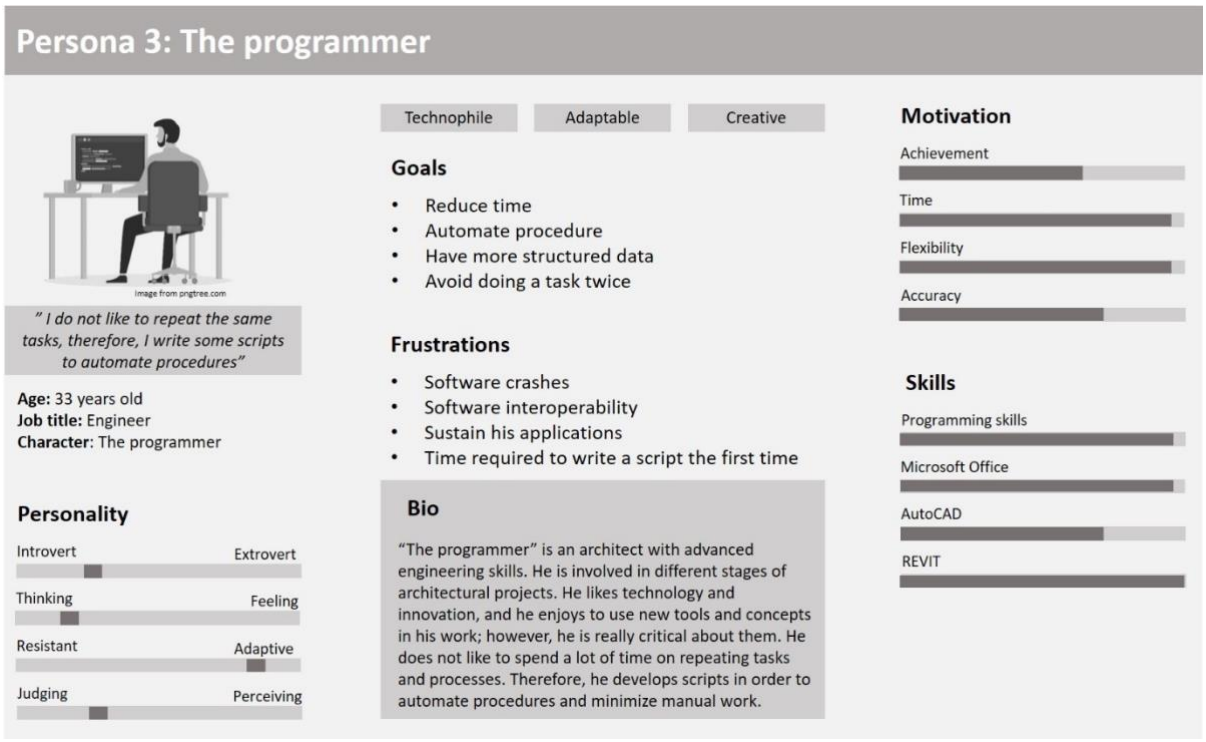

FIG. 6: Full profile of persona 3, the programmer.

4. DISCUSSION

The application of LCC is highly dependent on the adoption of the processes and tools by the practitioners, and therefore any new intervention in their work practices should be accomplished through their active participation. Consequently, the study places the practitioners in the centre of the research process and applies UCD methods, and specifically the concept of personas, in order to achieve the research objectives. Although UCD is a design-oriented methodology (LeRouge *et al.*, 2013), this study adopts a more analytical approach and rather than using personas as a design tool for LCC, this study uses personas for improving our understanding about users in general.

In this analytical context, the benefits of applying UCD in work practices are recognised in this study since the use of personas exposes valuable information on the characteristics and work processes of different types of users, something that is generally ignored in the academic literature on LCC. The results contribute also to an improved understanding of how people would like to work with LCC in practice by providing valuable insights on current and potential LCC users.

There is however one main restriction in the process of constructing personas, that is too restrictive in a more analytical study like this compared to a more design-oriented study, namely the designation between the different personas in Step 7. The designation between personas is useful in design-oriented processes where the design is focused on accommodating one dominant persona (Cooper *et al.*, 2014). However, this seemed to be a too strong limitation in an analytical perspective. Hence, this study aims to uncover the different user types instead of eliminating them or narrowing the research focus to only one dominant persona. Therefore, this study does not prioritize between the personas. Instead, it emphasizes the diversity of users and underlines the importance of thinking in precisely that diversity when developing interventions for increasing the application of LCC in the AECO industry. Failure to do so will seriously hamper the available intervention options and reduce the likelihood of success of adoption when developing new tools.

Moreover, the results highlight the diverse types of users by explicitly pointing out three different user personas. A significant difference between the three constructed personas is the way of working with technology and processing data, reflecting in three different methods of data integration methods that are summarized in Table 9.

TABLE 9: Personas in relation to data processing, data integration methods and tools requirements

	The clip-boarder	**The spreadsheet expert**	**The programmer**
Data processing	Manually select, copy and paste data from one application / position to another	Export and import data from an application to another in csv file / spreadsheet	Exchange data between applications automatically by using programming
Data integration method	Independent and stand-alone tools	Set up pipelines between tools and uses spreadsheets as the mediator of calculations	Interoperability methods to link individual tools through file transformation
Tool requirements	Simple and easy to use tool that include default values	A tool in a spreadsheet format, where data can be imported and exported easily	An open tool that supports interoperability

This increases our awareness that there are at least three different approaches in relation to tools and processes that should be taken into consideration when developing new solutions. While the findings of this study on users are related to LCC application, it also discloses different approaches to the use of digital technologies in general and thus important differences in the requirements of users towards not only LCC tools, but digital technologies in general.

As indicated in Table 9, the *clip-boarder persona* would benefit from a simple stand-alone tool that contains a number of default values in order to reduce manual work and minimize uncertainty about data. The *spreadsheet expert* persona on the other hand will benefit from tools in for example spreadsheets format that offer csv/spreadsheet import and export features. Finally, a tool that support interoperability will be valuable for *the programmer* persona, who could be able to automate their procedures.

In summary, rather than simplistically dividing practitioners into the binary basis of being either an LCC user or a non-LCC user, this study urges a more reflective approach with a stronger awareness of users' diversity and emphasis on the need for understanding the different users and their different requirements before designing tailor-

made solutions. Being sensitive to these differences and the diversity of users encourages a more pluralistic approach towards developing tools, practices and data that may in turn increase the chances of implementing LCC in the AECO industry and ultimately improve the economic sustainability of buildings and constructions. Although this study focuses on LCC and its application in the Danish AECO industry, the methodological approach used in this research is relevant and useful not only for either LCC or the Danish industry but can be replicated generally for revealing insights into users and their practices, which can support the development of novel tools and processes in other contexts and industries.

5. CONCLUSION

This study adopted user-centred design methods and specifically the concept of personas to increase our understanding on the diversity of LCC users towards their data management approaches, and how they apply different technologies and tools in the AECO industry by recognizing their characteristics and understanding their aspiration and work practices. A Danish architectural firm was used as a case study for the analysis, and data from users was collected through both qualitative and quantitative methods.

For constructing personas, the eight principle steps that are proposed by Alan Cooper was followed systematically (Cooper *et al.*, 2014). The only step that is not followed in this process is the designation between the constructed personas, as it is suggested in step 7 of this methodology. Despite the benefits of focusing on one dominant personas in design-oriented studies, the designation between personas is a strong limitation in analytical processes. Hence, this study does not prioritize between personas. Instead, it emphasizes the diversity of users and underlines the importance of acknowledging that diversity when developing novel processes and tools.

The analysis resulted in the construction of three personas:

1) *The clip-boarder* persona, who usually copies and pastes data from one application to another since he wants to have the control of the process. However, he spends a lot of time on manual work.

2) *The spreadsheet expert* persona, who imports and exports data in csv files/spreadsheets. However, she is challenged by correcting errors and structure data in spreadsheets.

3) *The programmer* persona, who uses programming language for transferring data from one application to another, since he wants to automate procedures, avoid repetitions of tasks and save time. However, he struggles with sustaining the scripts and the lack of software interoperability.

By constructing user personas, this study reveals valuable insights on how people work with technology in practice. The analytical approach emphasizes the importance of recognizing the diversity of users and their different approaches with regard to work processes and data integration instead of distinguishing them on the basis of being either LCC users or non-users. In relation to LCC, the three personas indicate three different approaches towards adopting LCC in design practices. Hence, the constructed personas can be used for developing future policies, new design practices and research and development activities that more adequately reflects users' interaction with digital technologies and extract design requirements for developing novel LCC processes and tools that may stimulate a stronger adoption of LCC in the AECO industry.

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