A survey of building design practitioner perceptions of ventilative cooling in their building design processes

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ABSTRACT

Buildings account for 40% of EU energy consumption and 36% of the energy related greenhouse gas emissions at present. Consequently, the net zero target set by Energy Performance of Building's Directive by 2050 for building stock is ambitious to achieve. The often default design choice to adopt mechanical cooling in non-domestic buildings highlights the lack of robust decision support tools or frameworks available to designers to properly evaluate ventilative cooling as a realistic alternative. Recent research suggests that the initial or concept design stage of a building project is a high leverage point in the design cycle to properly influence a building's design to avoid 'locking in' vulnerability at later stages due to retrospective value engineering efforts. Properly accounting for the potential of ventilative cooling solutions to mitigate risks against external disturbances to the indoor thermal environment such as heat waves as a result of climate change, as well as other performance limiting factors (i.e. air and noise pollution, power outages etc), is important to avoiding the selection of emissions intensive alternatives. A critical review of existing design processes followed by architects in practice completed as part of this study suggests that the pre-design phase and the schematic design phase of any building are the two crucial phases in any architectural design process. In these two stages, the information about a building's purpose, site, local micro-climate, client's expectations, and local legislations influences the building's overall shape, internal layout and morphology. This paper presents initial findings from a survey of industry experts about their design practices and experienced based approaches to designing ventilative cooling in low energy buildings at the concept design stages. The survey data was analysed through a mixed-methods approach (quantitative for closed-ended questions and qualitative for open-ended questions). This survey informed the ongoing development of the conceptual design framework within the Technical committee (TC) within the European Committee for Standardization (*CEN Technical Bodies - CEN/TC 156/WG 21*, n.d.; *CEN/TC 156/WG 21 - Revision of Calculation Standards EN15241, 15242 and 15243*, n.d.) scope. The framework which would be developed as an outcome of the completed study would have the potential to significantly improve the operational performance of ventilative cooling systems through early-stage interventions in building design that lead to more robust strategies that limit the need for mechanical cooling.

KEYWORDS

Design practice, design processes, ventilative cooling, design guidelines, passive cooling, building design practitioners, resilience in built environment.

1 INTRODUCTION

In the broader context of climate change and global warming, there is an increased importance of energy efficiency in buildings worldwide and a large proportion of a building's energy consumption, comes from heating, ventilation, and air conditioning (HVAC) services to make them comfortable for human living. According to a report by the International Energy Agency (2018) focusing on The Future of Cooling (opportunities for energy-efficient air conditioning) (*The Future of Cooling – Analysis - IEA*, 2018.) carbon emissions from buildings have increased by 50% in the period between 1990 and 2019. This is partly because of urban densification and increased floor area per person caused by building more and more buildings. In addition, the global average cooling demand in commercial buildings is likely to be increased by 275% by 2050 due to rising air conditioning demands (Santamouris, 2016; *The Future of Cooling – Analysis - IEA*, 2018.) Yamina Saheb, one of the authors of the IPCC (*Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments — IPCC*, n.d.) report claimed our buildings to be wrongly designed (*Our Buildings Are "Wrongly Designed," According to IPCC Report Author*, n.d.) in the context that many of our buildings have active heating, mechanical and cooling systems that consume energy which shows a discrepancy in the way buildings are designed. There has been an increasing interest in ventilative cooling and resilient cooling concepts in recent literature and standards (Attia et al., 2021; Kolokotroni & Heiselberg, n.d.; O' Donovan et al., 2021; Tavakoli et al., 2022) but the implementation of these concepts is still not visible in building design practices. Although, the application of ventilative cooling principles and strategies are believed to be a solution against threats of heat waves and climate change (Alonso et al., 2015; Breesch et al., 2018; Sengupta et al., 2020; Song et al., 2022). IEA EBC annex 62 State of the Art Review report (2018) recently defined VC as, '*The application of ventilation flow rates to reduce the cooling loads in buildings. VC utilizes the cooling and thermal perception potential of outdoor air. The air driving force can be natural, mechanical or a combination*' (Kolokotroni & Heiselberg, n.d.).

A critical review of building design processes studied in the context of ventilation in the built environment reflects a lack of consensus among building design stakeholders in properly accounting for the cooling needs of buildings against future climate threats, such as heatwaves, at conceptual and pre-design phases, in advance of the detailed design. Participatory methods, which offer a better mode of understanding the context of how a building is designed and at what stage the decision about "cooling the building" is taken, have received less attention in this perspective. For instance, the RIBA Plan of Work (*RIBA Plan of Work 2020 Overview RIBA Plan of Work*, 2020) shows various stages of the Architectural Design Process as pre-design, schematic design to design development stages but it does not explicitly mention the considerations of indoor environmental quality at the initial stages rather sustainability checks are considered at final stages of building design such as commissioning, construction and building regulations which may include decisions of ventilation and indoor comfort. Likewise, Polat Darcin (Darçın, 2020) developed a conceptual architectural design process for ventilation in the built environment from a research perspective but did not apply it to design practice. Ahmed A.Y. Freewan (Freewan, 2019) showed an integrated design approach for passive cooling devices by a design matrix named SARS (Storing, Allowance, Removal or Slowing) but did not demonstrate its application in architectural practices. A brief review of building design and airflow modelling tools (*Best Directory | Building Energy Software Tools*, n.d.) also suggests that there is no clear design process developed that can be followed in design practices that would improve the performance (and by extension uptake) of ventilative cooling strategies from early design stages. Likewise, a brief process of design in general has been presented by CIBSE Environmental Design Guide A (CIBSE, 2015). Cevrede et al. 2020 developed a conceptual architectural design process for ventilation in built environment (Çevrede et al., 2020), a simulation based framework was developed Rahif et al. 2022 (Rahif et al., 2022) to evaluate resistivity of cooling strategies in buildings against overheating impact of climate change, yet it was not well demonstrated by multiple cooling strategies and real multi-zone reference buildings modelling. All the processes developed in these studies are not detailed and not applied in real life scenarios to assess their application and whether they work for the industry experts.

2 METHODOLOGY

This paper presents the results from a survey targeted at Building Design Practitioners in the United Kingdom and Ireland region with the title; "Perception of Ventilative Cooling in Building Design Practices" and links it to the work done so far on ventilative cooling standards within the scope of Technical Working Group for Ventilative Cooling Standards (TC/156 WG21). The survey contains a mix of both open-ended and closed-ended questions. For this study, only the results obtained in the first three weeks of running the survey are presented, therefore, only completed responses are considered. The survey is aimed to continue for at least 3-4 months to obtain good quality data and sample size. The survey is a first step in the planned methodology of the full research study; "*Development of a building design process for improving the thermal resilience of non-domestic buildings using ventilative cooling solutions*" as is indicated in Figure A1 (Appendix A).

2.1 Development of the survey

The survey was developed to understand the perception of the term "ventilative cooling" in architectural and construction practices and was divided into seven parts. The overall hierarchy of the parts of the survey can be elaborated by Figure 1.

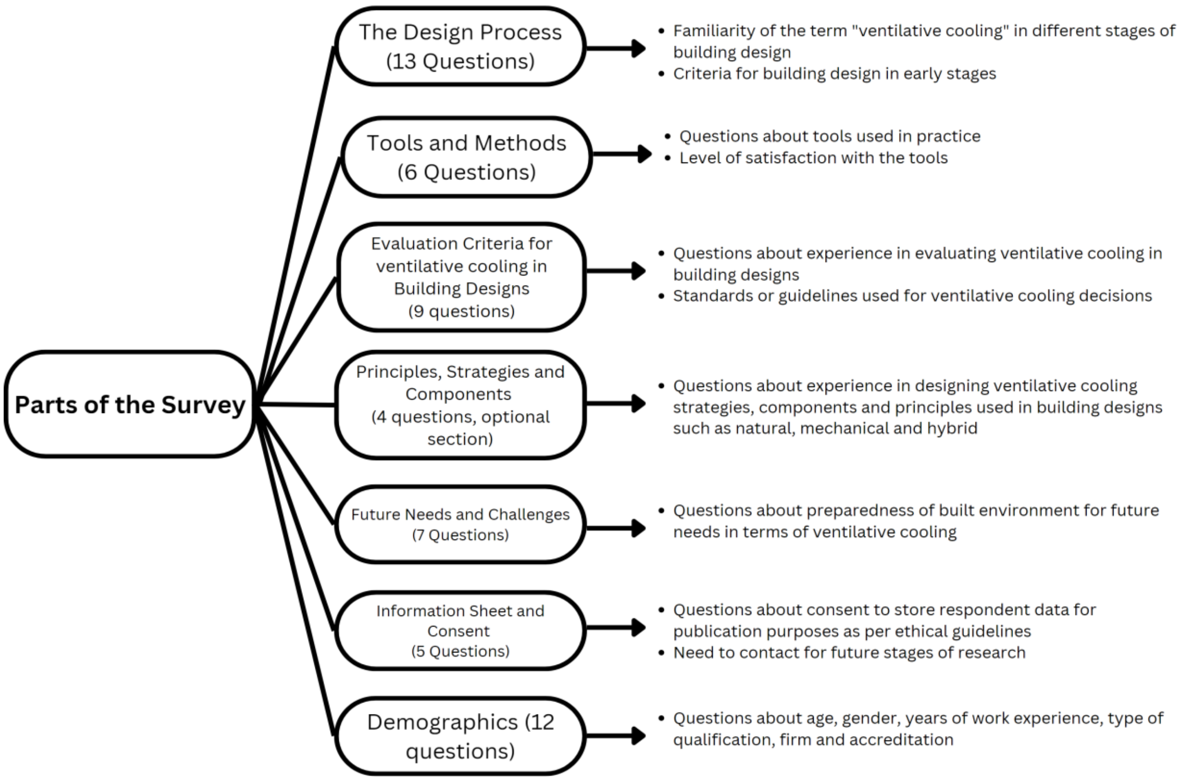


Figure 1: Summary of 57 questions used in the survey

An engineer, a researcher and a professor were identified from the network of corresponding authors of the paper to preliminary test and comment on any technical errors with the survey and to point out any issues with consistency and structure of the questionnaire. Respondents gave some suggestions about the questions which were incorporated. Overall, they were satisfied with the structure and format of the survey. Munster Technological University's

Research Ethics Committee also approved the research in line with all ethical requirements (Approval number: MTU-HREC-MR-22-001-A).

2.2 Respondents of the survey

In this study, building design experts such as architects, building service engineers, design managers, sustainability experts in the United Kingdom and Ireland region were targeted. LinkedIn was used to identify their profiles by searching through their current job description, years of experience (more than five) and their current affiliation with an architectural design or engineering firm. Many email addresses were collected through the "contact info" section of LinkedIn profiles of respondents. In addition, many experts were identified through the professional network of the corresponding authors. Moreover, the architectural practice directory of The Royal Institute of the Architects of Ireland (https://www.riai.ie/work-with-an-architect/find-an-architect/practice-directory/) (*Practice Directory | RIAI.Ie (The Royal Institute of the Architects of Ireland)*, n.d.) was also used to identify architectural firms in Ireland. The response rate was consistently slow at 30% in the first two weeks, however, not all respondents answered all the questions completely. The demographics of the respondents who completed the survey is presented in Table 1. The online questionnaire was delivered through Survey Monkey link (https://www.surveymonkey.com/r/YMNY2VT).

Table 1: Demographics of Respondents

Demographic	Architect	Engineer	Architectural Technologist	Other	Total
Gender					
Male	7	2	1	1	11 (78%)
Female	2	0	0	0	2 (14.3%)
Prefer Not to Say	1	0	0	0	1 (7%)
Age					
35-44	2	0	0	0	2 (14%)
45-54	4	1	0	1	6 (43%)
55-64 65+	4	1	1	0	6 (43%)
Highest Qualification					
PhD	0	0	0	1	1 (7%)
Masters or Postgraduate	7	1	0	0	8 (57%)
Bachelors	2	1	0	0	3 (21%)
Diploma	0	0	1	0	1(7%)
Other	1	0	0	0	1(7%)

3 RESULTS

The results of four sections of the survey aligning with the themes of the conference are briefly presented as follows;

3.1 The Design Process

The first question in this section was about the criteria for designing buildings and if cooling is a criterion. The results can be shown by the Table 2 where all respondents agreed that cooling is an essential criterion in their respective countries while none of them excluded it as a design criteria.

Table 2: Responses of Questions related to the term “ventilative cooling” and the “Design Process” in the Survey

Questions	Answer Option 1	Answer Option 2	Answer Option 3
Would you identify cooling of the indoor environment in buildings an important design criteria amongst your profession in your particular climate/country?	Yes, it is an important criteria(85.71%)	Yes, it is a criteria but it's not important (14.29%)	No, it's not a criteria (0%)
Are you familiar with the term “Ventilative Cooling”?	Yes (71.43%)	No (28.57%)	

The respondents were also asked whether they were familiar with the term “ventilative cooling” and it turned out a strong majority (71.43%) of the respondents were familiar with the term as shown in Table 2. Around 28.57% were not familiar. After a literature survey of the architectural design processes (*RIBA Plan of Work 2020 Overview RIBA Plan of Work*, 2020; *The 5 Phases Of The Architectural Design Process, Explained*, n.d.; *The 7 Phases of the Architectural Design Process - 2022 - MasterClass*, n.d.; Saeid & Mahmoodi, 2001); we proposed the initial question to the architects presenting a diagram in front of them where the architectural design process consists of 6 stages, i.e. pre-design phase, schematic design phase, design development phase, bidding & construction administration, commissioning and post occupancy evaluation. The initial hypothesis of this research was stated in this diagram that “*ventilative cooling decisions are not taken at the early design stages* “which we decided to test by conducting the survey. To the extent that the respondents agree or disagree with our understanding of the building design process and our hypothesis, can be seen in Figure 2, where 50% of the total respondents agreed with the process diagram presented to them, 43% disagreed (14% “strongly disagreed” and 29% “Disagreed”) and 7% had no opinion on the process and the hypothesis we stated.

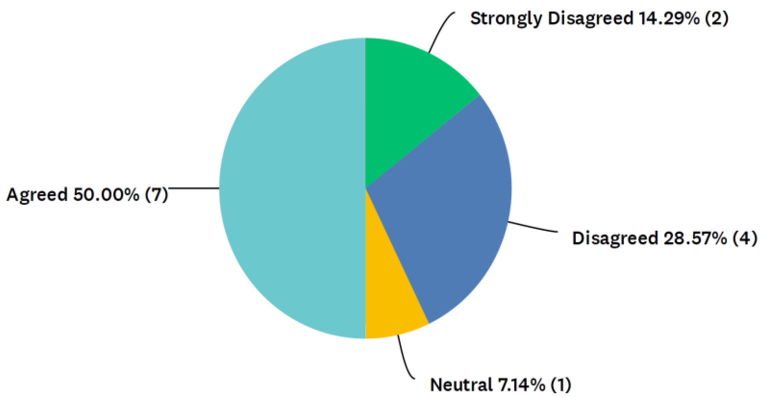


Figure 2: The extent to which respondents agreed or disagreed with the building design process diagram presented to them.

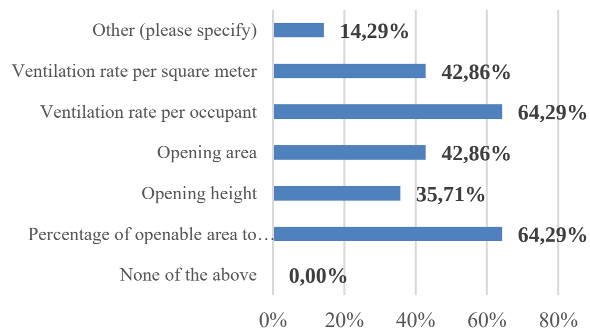
3.2 Tools and Methods

Around 21% of the respondents do not use any design tools to make any ventilative cooling decision and around 50% sometimes use a design tool while 29% of the respondents use the tool while making a ventilative cooling decision. The most popular software used by the respondents is Passive House Planning package (PHPP) with around 50% of the respondents using it, and the second most popular tool is Integrated Environmental Solutions (*Integrated Environmental Solutions | IES*, n.d.) with around 33% of the respondents using it in their design practices. The respondents who use the tools mostly use them in schematic and design development phases. Finally, some of the respondents do not use any tools, because they do not think of themselves as experienced in using these tools and therefore, they rely on the advice of engineers on this topic

Around 54% of the respondents are not satisfied with the current tools in the market in terms of their ability to suggest ventilative cooling design options. Some of the improvements suggested by respondents to make the tools better include ability to include parametric analysis, increasing the speed and making them cost effective for use by Architects. Some Architects also believe that there is a gap between software simulations and actual performance of the building designs which needs to be reduced. Also, the ability to overestimate the mechanical cooling demand by the tools in order to follow building regulations is also a problem with the current tools highlighted by a respondent. Other than the tools, around 64% of the respondents rely on their professional experience and 28% of the respondents highlighted the importance of other means e.g. technical guidance documents, advice of engineers, cost implications and user comfort to make an efficient ventilative cooling strategy.

3.3 Evaluation Criteria for Ventilative Cooling in Building Designs

In this section the respondents were asked if they have any experience in evaluating ventilative cooling potential of their building designs and what criteria they use for the purpose. Half of the respondents were experienced and the other half were not in evaluating the ventilative cooling potential of their designs. In addition, the top two variables that the respondents consider at the early design stage for ventilative cooling systems are ventilation rate per occupant and percentage of openable area as shown in Figure 3. While evaluating comfort performance in their building designs, the majority of respondents selected "% of hours > 25°C" as the upper temperature threshold for consideration as shown in Figure 3 below.



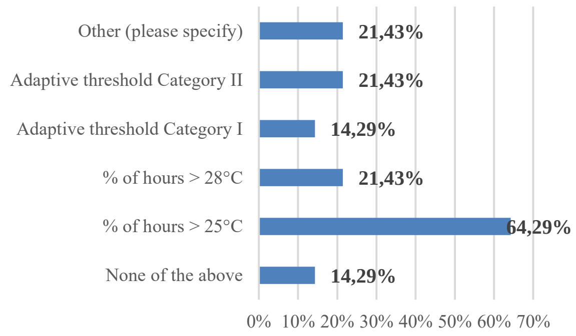


Figure 3: Results of the questions, *"Which of the following metrics or variables do you consider at the early design stage for ventilative cooling systems?"* and *"When evaluating comfort performance in your designs, what upper temperature thresholds do you consider?"* from left to right respectively.

3.4 Future Needs and Challenges

Results of some of the questions and their answers; pertaining to future needs and challenges faced by built environment professionals in improving the resilience of buildings are presented in Table 3. It can be said that the majority of respondents (93%) are familiar with the importance of ventilative cooling in delivering a carbon-neutral built environment. However, about 71% of the respondents believe that built environment design industry is not ready to design buildings for extreme climate events and the buildings of today are not ready for such events in the future.

In addition, 57% of the respondents believe that natural ventilation alone does not work satisfactorily as a cooling solution against future climate change.

Table 3: Responses of Questions related to Future Needs and Challenges of Ventilative cooling in Building Designs

Questions	Answer Option 1	Answer Option 2
Do you think that the built environment design professionals are prepared for accounting for extreme future climate events, such as heat waves, while designing buildings today that will be used many years from now?	Yes (28.57%)	No (71.43%)
In your experience does Natural Ventilation work satisfactorily as a cooling solution against future climate change?	Yes (42.86%)	No (57.14%)
Can Ventilative Cooling play a role in delivering a carbon neutral built environment?	Yes (92.86%)	No (7.14%)

An overall mind map can be generated from the overview of survey results which is represented by Figure 4. The gaps in research and future steps pertaining to easy tools or early design stages are mentioned and an interconnection between all the stages is presented by the dotted circular line. The overall result is that design is an iterative process and the core design team is always at the centre of making design decisions as the project progresses.

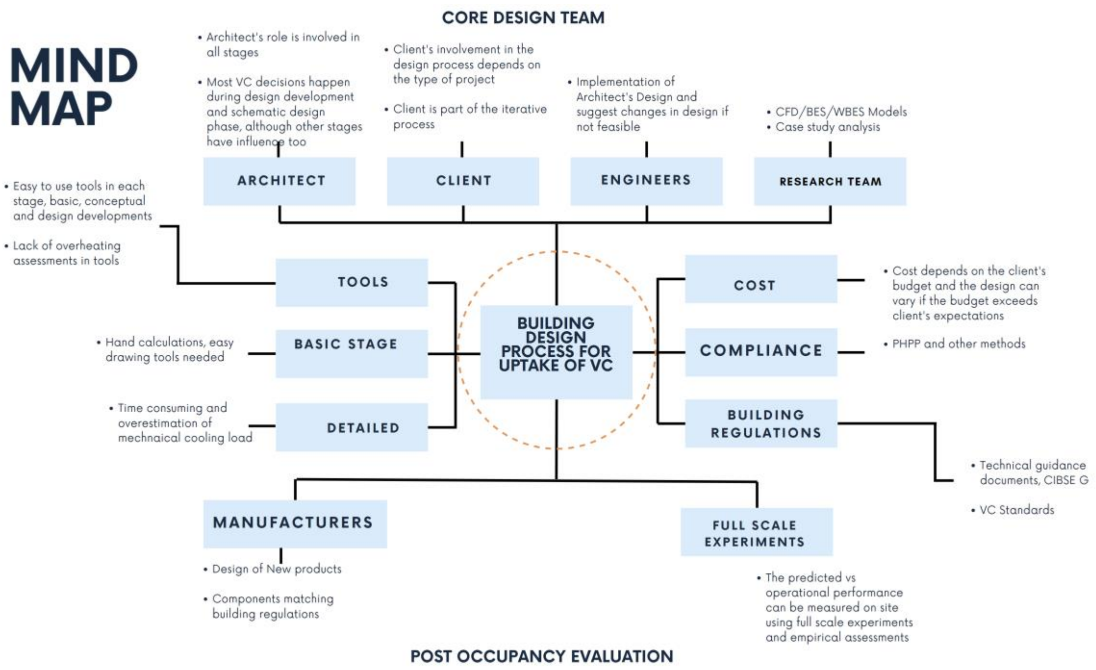


Figure 4: Visualization of the survey responses of how information flows in the design process

4 VENTILATIVE COOLING STANDARDS

Currently work is underway within TC/156 (*CEN Technical Bodies - CEN/TC 156/WG 21*, n.d.) to develop a new design guide to assist with designing ventilative cooling at building design practices. The work done by far on Ventilative Cooling standards update (Table A1 in Appendix A) was used to develop the survey questions. However, if a comparison is made between the results of the survey, the architectural design processes as covered in the section 3 and the work on standards by far, it can be inferred that Architects do not use a separate conceptual and basic design term, rather the terms used are basic as the simplest stage of design and conceptual or schematic phase is the next phase of design. In other words, the ventilative cooling standards are more technical from the perspective of the Architects. Further stages of study would address if the Architects can find the ventilative cooling guides useful in any stage of their process and if there is a framework that can be developed further that can help in the uptake of ventilative cooling standards from the early design stages.

5 CONCLUSIONS

In this paper, only prominent results from four sections of the survey are presented to understand the perception of the term "ventilative cooling" in the overall building design process used in design practices in the UK and Ireland region. The survey results will be analysed in detail over the next few months and a statistical analyses will also be carried out on receiving a good quality data. From the results, it is evident that the building design practitioners are familiar with the term "ventilative cooling" as the name suggests but they admit the lack of decision-making frameworks and tools in promoting the uptake of VC solutions in their building designs to make buildings resilient against threats of heat waves. The results are also subject to change on receiving more responses from the industry experts in building design. This is an ongoing survey which will last for about three months providing a direction to design the next stages of the research, i.e. interviews and a possible placement at an architectural design practice to validate the design process by a case study building. This study provides an opportunity to find a case study building that has adequate ventilative cooling solutions designed and that is resistant to the effects of climate change. Identification of the design process used in such a building can help in development and verification of the design process intended in this research.

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