

AUGMENTED REALITY FOR HVAC SYSTEM OPTIMIZATION IN HIGH RISE BUILDINGS

Samidini Yanudha Athukorala

209224N

Master of Science in Project Management

Department of Building Economics
Faculty Of Architecture

University of Moratuwa
Sri Lanka

December 2025

AUGMENTED REALITY FOR HVAC SYSTEM OPTIMIZATION IN HIGH RISE BUILDINGS

Samidini Yanudha Athukorala

209224N

Thesis/ Dissertation submitted in partial fulfilments of the requirements of the degree
Master of Science in Project Management

Department of Building Economics
Faculty Of Architecture

University of Moratuwa
Sri Lanka

December 2025

DECLARATION

I hereby declare that this research is a result of my own work. This has not been submitted for any degree or diploma at this or any other institution of higher education. All sources used in the course of this research have been duly acknowledged and appropriately cited in the text and in the list of references.

Further I acknowledge the immense contribution of my research supervisor Dr Tharusha Ranadewa towards the completion of the research. I confirm that articles or any other publication based on this research will not publish without mentioning the name of research supervisor as coauthor of this research.

.....

Athukorala S. Y.

Date

The above named has carried out this research for the Dissertation under my supervision.

.....

Dr. (Mrs) Tharusha Ranadewa

Date

ACKNOWLEDGEMENT

This dissertation is the culmination of my dedicated effort and is deeply indebted to the guidance, support, and encouragement I have received from numerous individuals and institutions throughout the research and writing process.

First and foremost, I extend my sincere gratitude to my dissertation supervisor, Dr. (Mrs.) Tharusha Ranadewa, whose scholarly insights, rigorous guidance, and unwavering encouragement were instrumental to the quality and successful completion of this study. Her expert knowledge in the field and constructive feedback profoundly shaped the development of this research.

I also wish to acknowledge the invaluable contributions of all interview and questionnaire respondents, industry professionals, and subject matter experts who generously shared their time, insights, and technical experiences, enriching the empirical foundation of this research. Their real-world perspectives were crucial in contextualizing the role of augmented reality within the domain of HVAC system optimization in complex high-rise environments.

My profound appreciation goes to my family, friends, and colleagues, whose constant moral support, patience, and motivation sustained me through challenging moments. Their belief in my capabilities inspired me to persevere and complete this work.

Lastly, I am grateful to all the academic staff and administrative staff who provided the necessary resources, guidance and support during my postgraduate studies. Each contribution, played a meaningful part in shaping this dissertation.

To everyone who supported me in this academic journey.

ABSTRACT

Augmented Reality for HVAC System optimization in high rise building

The performance of Heating, Ventilation, and Air Conditioning (HVAC) systems in high-rise buildings is frequently compromised through design inefficiencies, installation issues and suboptimal maintenance work, resulting in compromised indoor air quality, higher operational expenditures and low occupant comfort. This study explores the prospects of Augmented Reality (AR) as a multi-phase enabler for the optimization of HVAC systems during design, installation, and maintenance phases. A mixed-methods approach was adopted, combining a literature review, questionnaire surveys and expert interviews to identify prevailing HVAC issues, assess AR's applicability, and evaluate barriers.

Findings indicated that problems during the design phase include incorrect duct sizing, inconsistencies between client and architect specifications, and incorrect cooling load estimates. Issues during the installation phase are primarily associated with poor craftsmanship, dependence on incorrect design guidelines, and substandard supplies, whereas problems in the maintenance phase involve poor maintenance practices, unsuitable repair techniques, and poor material quality. Triangulated proof substantiates AR's capacity to augment system performance by early clash detection, immersive client involvement, enhanced coordination, real-time monitoring, and hands-free troubleshooting, leading to reduced downtime, decreased operational expenses, and improved asset management.

However, adoption is hindered by high implementation costs, skills, knowledge gaps, organizational resistance, inadequate infrastructure, data security and regulatory concerns, limited HVAC-specific AR content, and environmental constraints affecting accuracy. AR has been found to enhance the efficiency of HVAC systems and lifecycle performance of high-rise building assets significantly provided financial, technical, and organizational obstacles are systematically mitigated. Recommendations involve special training programmes, infrastructural upgrading, cost-optimization measures, and creation of industry-specific AR apps enabling sustainable adoption.

Keywords: Augmented Reality, HVAC Systems, High-Rise Buildings, System Optimization, Building Services,

TABLE OF CONTENTS

DECLARATION	i
ABSTRACT.....	iii
TABLE OF CONTENTS	iv
LIST OF FIGURES.....	ix
LIST OF TABLES	x
LIST OF ABBREVIATIONS	xi
LIST OF APPENDICES	xii
CHAPTER 01.....	1
1.0 INTRODUCTION.....	1
1.1 Background.....	1
1.2 Research problem	3
1.3 Aim & Objectives.....	3
1.3.1 Aim.....	3
1.3.2 Objectives.....	3
1.4 Research methodology	4
1.4.1 Literature review	4
1.4.2 Questionnaire survey	4
1.4.3 Expert interviews	4
1.5 Scope & Limitation	4
1.6 Chapter breakdown.....	4
1.7 Chapter Summary	5
CHAPTER 02.....	6
2.0 LITERATURE REVIEW.....	6
Section 01	6
2.1 Introduction	6

2.2 High rise building construction	6
2.3 Problems in high rise building construction	6
2.4 Introduction to HVAC Systems.....	8
2.4.1 Global & Sri Lankan market demand for HVAC systems	8
2.4.2 Green buildings, energy saving & HVAC systems	9
2.5 HVAC System types in modern market	10
2.5.1 Growing demand of HVAC products in modern markets	10
2.5.2 Commonly used HVAC systems in high rise architecture.....	11
2.6 HVAC System challenges	13
2.6.1 Common HVAC problems in high rise buildings.....	14
2.6.2 Design-induced challenges in HVAC systems	15
2.6.3 Installation-induced challenges in HVAC systems.....	17
2.6.4 Maintenance-induced challenges in HVAC systems.....	18
2.6.5 Factors contributing to HVAC system failures.....	19
2.6.6 Effective solutions to address common HVAC system issues	19
Section 02.....	20
2.7 New technologies can be used to overcome the issues	20
2.7.1 Vertical alignment.....	20
2.7.2 eXtended reality	20
2.7.3 Big data	21
2.7.4 Augmented reality.....	21
2.8 Augmented reality	22
2.8.1 Definition	22
2.8.2 Core components of AR.....	23
2.9 Application of augmented reality in different fields	24
2.10 Augmented reality products available in market.....	24
2.11 Benefits of Augmented reality.....	27

2.12	Barriers of Augmented reality	27
2.13	Further developments identified on Augmented reality	28
2.14	Augmented reality implementation for HVAC systems in high rise buildings 29	
Section 03		29
2.15	Conceptual framework	29
2.16	Chapter summary	31
CHAPTER 03		32
3.0 RESEARCH METHODOLOGY		32
3.1	Introduction	32
3.2	Research design	32
3.3	Research approach	32
3.4	Types of research approaches	32
3.5	Research methods	33
3.5.1	Literature review	34
3.5.2	Questionnaire survey	34
3.5.3	Expert interviews	34
3.6	Data analysis techniques	35
3.6.1	Questionnaire survey analysis	35
3.6.2	Expert interviews analysis	35
3.7	Research process	36
3.8	Chapter summary	37
CHAPTER 04		38
4.0 ANALYSIS & RESEARCH FINDINGS		38
4.1	Introduction	38
4.2	Questionnaire survey	38
4.2.1	Objectives of questionnaire survey	38

4.2.2 Respondents in questionnaire survey	38
4.2.3 Findings & analysis of questionnaire survey	39
4.2.3.1 Findings of the factors affect significantly on selection of HVAC system 40	
4.2.3.2 Findings of the common issues effect on selection of HVAC systems in high-rise buildings	42
4.2.3.3 Findings of the different stages cause issues of HVAC system in high rise buildings.....	43
4.2.3.4 Contribution of SBS & Stack effect for HVAC systems in high rise building	47
4.2.3.5 Contribution of visualization technology to overcome HVAC systems in high rise building	48
4.3 Expert interviews	49
4.3.1 Objectives of expert interviews	49
4.3.2 Respondents in expert interviews	49
4.3.3 Findings & analysis of expert interviews.....	52
4.3.3.1 Findings of industry experience Vs familiarity with AR.....	52
4.3.3.2 Findings on adopting visualization technologies	52
4.3.3.3 Findings on implementing AR as the visualization technology	53
4.3.3.3 Findings on benefits of implementing AR technology	54
4.3.3.4 Findings on barriers of implementing AR Technology	57
4.3.3.5 Develop strategies for successful AR implementation in HVAC optimization	59
4.4 Analytical discussion of literature and empirical pattern matching.....	61
4.5 Comparative Discussion: Global vs. Sri Lankan Context	70
4.5 Chapter summary	70
CHAPTER 05.....	71
5.0 CONCLUSIONS & RECOMMENDATIONS	71

5.1 Introduction	71
5.2 Conclusion.....	71
5.3 Recommendations	74
5.4 Limitations.....	75
5.5 Further research	76
5.5 Chapter summary.....	76
REFERENCES.....	77
APPENDIX A - QUESTIONNAIRE SURVEY.....	94
COVERING LETTER FOR QUESTIONNAIRE SURVEY.....	94
APPENDIX B - EXPERT INTERVIEW GUIDELINE	99
COVERING LETTER FOR INTERVIEW GUIDELINE	99
INTERVIEW GUIDELINE	100
APPENDIX C - QUESTIONNAIRE SURVEY ANALYSIS	104

LIST OF FIGURES

Figure 1. 1 Chapter Breakdown	4
Figure 2. 1 HVAC Classifications.....	10
Figure 2. 2 HVAC Equipment Market	11
Figure 2. 3 Common HVAC Systems in the market.....	11
Figure 2. 4 HVAC Systems	13
Figure 2. 5 HVAC & Sick Building Syndrome	14
Figure 2. 6 Heat Column Generation in High Rise Buildings.....	15
Figure 2. 7 Stack Effect in High Rise Buildings	15
Figure 2. 8 Causes for HVAC Problems	19
Figure 2. 9 Augmented Reality	21
Figure 2. 10 Definitions of Augmented Reality	22
Figure 2. 11 Components of AR	23
Figure 2. 12 Tasks in Augmented Reality	23
Figure 2. 13 Conceptual Framework.....	29
Figure 3. 1 Comparison between qualitative, quantitative, and mixed research approaches	33
Figure 3. 2 Research process.....	36
Figure 4. 1 Years of experience of the respondents in questionnaire survey.....	39
Figure 4. 2 Likert scale interpretation	39
Figure 4. 3 Factors affecting significantly on selection of HVAC system.....	41
Figure 4. 4 Common HVAC issues in High Rise Buildings.....	42
Figure 4. 5 Design, Installation, Maintenance issues of HVAC system	43
Figure 4. 6 Summarized HVAC system issues in different stages.....	46
Figure 4. 7 Contribution of SBS & Stack effect for HVAC issues	47
Figure 4. 8 Contribution of Visualization Technology to overcome HVAC systems in high rise building.....	48
Figure 4. 9 Responses of Interviewees regarding benefits of AR.....	55
Figure 4. 10 Interviewee comments on barriers of implementing AR Technology.	57
Figure 4. 11 Literature & Empirical mapping of HVAC performance challenges ..	61
Figure 4. 12 Literature & Empirical mapping of benefits & barriers of AR.....	64
Figure 4. 13 Final Framework for high rise HVAC optimization using Augmented Reality	67

LIST OF TABLES

Table 2. 1	Problems in High Rise Buildings	6
Table 2. 2	Factors Influencing HVAC System Selection.....	8
Table 2. 3	HVAC system comparison	12
Table 2. 4	Common Problems in HVAC Systems	13
Table 2. 5	HVAC problems related to design Issues.....	16
Table 2. 6	HVAC problems related to Installation Issues	17
Table 2. 7	HVAC problems related to Maintenance Issues	18
Table 2. 8	Current Market Offerings in AR	24
Table 2. 9	Benefits of AR.....	27
Table 2. 10	Barriers of AR	28
Table 4. 1	Work experience of respondents	38
Table 4. 2	Factors affect significantly on selection of HVAC System.....	40
Table 4. 3	Common issues of HVAC System in high rise buildings	42
Table 4. 4	Different stages cause issues of HVAC System in high rise buildings...	43
Table 4. 5	Design stage issues of HVAC System in high rise buildings.....	44
Table 4. 6	Installation stage issues of HVAC System in high rise buildings.....	45
Table 4. 7	Maintenance stage issues of HVAC System in high rise buildings	45
Table 4. 8	Contribution of SBS & Stack Effect for HVAC systems in high rise building.....	47
Table 4. 9	Profile of Expert Interview Participants	50
Table 4. 10	Interviewee comments on adopting visualization technologies	52
Table 4. 11	Interviewee comments on adopting AR technologies	53
Table 4. 12	Proposed strategies for successful AR implementation in HVAC optimization.....	60

LIST OF ABBREVIATIONS

AR	: Augmented Reality
ASHRAE	: American Society of Heating Refrigerating and Air-Conditioning Engineers
HVAC	: Heat Ventilation & Air Conditioning
RICS	: Royal Institution of Chartered Surveyors
BIS	: Business Intelligence and Strategy
VRF	: Variable Refrigerant Flow
IAQ	: Indoor Air Quality
VA	: Vertical Alignment
WMR	: Weight means Rank
SD	: Standard Deviation

LIST OF APPENDICES

Appendix	Description	Page
Appendix A	Questionnaire Survey	100
Appendix B	Expert Interview Guideline	105
Appendix C	Questionnaire Survey Analysis	111