

**EVALUATION OF RISK MANAGEMENT  
FRAMEWORKS FOR HOSPITALS**

Wickramasooriyage Devmini Maheshani Kularatne

(198018J)

Degree of Master of Science

Department of Civil Engineering

University of Moratuwa

Sri Lanka

June 2020

# **EVALUATION OF RISK MANAGEMENT FRAMEWORKS FOR HOSPITALS**

Wickramasooriyage Devmini Maheshani Kularatne

(198018J)

Thesis submitted in partial fulfillment of the requirements for the degree Master of  
Science in Civil Engineering

Department of Civil Engineering

University of Moratuwa


Sri Lanka

June 2020

## Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

Also, I hereby grant to the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic, or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: .....  ..... Date: ..... 01.05.2021 .....

The above candidate has carried out research for the Master's thesis under my supervision.

Name of the supervisor: Dr C.S.A. Siriwardana

Signature of the supervisor: ..... Date: .....

## **Abstract**

Unlike disasters that arise from natural hazards, fire disasters can occur at any moment, in any place, if the proper precautions are not taken. The spreading of fire can more often cause disastrous results, such as loss of property, injuries, and death. Hospitals especially have a vulnerability to fire, considering the flammable materials present in the buildings such as medical gas, generator fuel, laboratory materials, high fire risk areas such as kitchens and generator room, a high waste generation which occurs in hospitals as well as the vulnerable people in the hospital such as patients with mobility issues. Therefore, fire risk management is essential for hospitals.

This research study focused on developing a risk management framework for hospitals focusing on fire hazards. The framework consists of two sections; a risk assessment tool that can be used to assess the fire risk performance of hospitals and a post-disaster activity list for hospitals after a fire hazard. The framework consists of three modules: design and construction, operation and maintenance, and fire hazard management. This framework can be used by hospital administrators to evaluate the current level of fire safety of the hospital. Thereby, the administration can analyze the weaknesses and take action to correct them. The post-disaster activity list contains actions related to the elements of people, buildings and critical infrastructure, hospital equipment, and material and post-disaster administrative work.

During the development and analyzing the applicability of the risk management framework, six governmental and 3 private-owned hospitals were assessed. The data collected revealed some key differences between the two types of hospitals. The private-owned hospitals showed a better level of preparedness for hospital fires as they had fire extinguishers and other fire protection systems which were updated regularly, had annual maintenance and testing of fire protection systems and annual fire training and fire drills for staff. In almost all of the surveyed government hospitals, these elements of preparedness were missing.

**Keywords:** safe hospital, fire safety, risk management framework, risk assessment tool, post-disaster management

## Dedication

*Fire exists the first in light, - And then consolidates, -  
Only the chemist can disclose - Into what carbonates*

*-Emily Dickinson-  
(1830-1886)*

To my parents,

Thank you,

For dousing those physical fires, I lit in my childhood,

but also,

For kindling the fires that were my thirst for knowledge

## **Acknowledgments**

I would like to express my heartfelt thanks to my research supervisor, Dr. Chandana Siriwardana for his guidance, suggestions, and motivation throughout the research study. His immense support allowed me to gain a wide exposure to the area of disaster risk reduction in the local and international arenas. I also express my sincere gratitude to Prof. Asoka Perera and Dr. Nimal Wijyaratna for their guidance and advice in this study.

I would also like to thank my colleagues, Mr. Hashan Hasalanka, Ms. Ishani Shehara, Mr. Kusal Rathnayake, Ms. Sonali Abeysinghe, and Mr. Thilanga Fonseka for their assistance during my data collection activities and participation in peer discussions relevant to the research study.

I also wish to thank Dr. H.B.D. Herath, Dr. A. Wedamulla and Dr. N. Wijesekara from the Disaster Preparedness and Response Division as well as Dr. K.A.L.C. Kodithuwakku from the Dengue Control Unit of the Ministry of Health, Sri Lanka for facilitating access to government-owned hospitals for case studies as well as the advice and guidance given throughout this research study.

Sincere thanks also go out to the administrative officials of the hospitals surveyed during the study for providing access to the hospitals. I would also like to thank the staff of each hospital for their help and cooperation during the data collection.

Finally, I would like to express my gratitude for the fire safety industry professionals, disaster management professionals and the medical professionals who helped during the course of the study.

Thank you,

Devmini Kularatne

## Table of Contents

Declaration .....	iii
Abstract .....	iv
Dedication .....	v
Acknowledgments.....	vi
Table of Contents .....	vii
List of Figures .....	xii
List of Tables .....	xvi
List of Abbreviations .....	xviii
1 Introduction to the Research Study .....	1
1.1 Background .....	1
1.2 Thesis Question .....	4
1.3 Problem Statement .....	5
1.4 Scope of the Study.....	5
1.5 Research Objectives .....	5
1.6 Outcomes.....	6
2 Literature Review.....	7
2.1 Disaster Risk Terminology.....	7
2.1.1 Hazard .....	7
2.1.2 Disaster .....	7
2.1.3 Exposure .....	7
2.1.4 Preparedness .....	7
2.1.5 Capacity .....	7
2.1.6 Vulnerability .....	7
2.1.7 Risk .....	8

2.1.8	Disaster Resilience .....	8
2.1.9	Safe Hospital .....	8
2.2	Disaster Profile in Sri Lanka .....	8
2.3	Fire .....	10
2.3.1	Introduction to Fire .....	10
2.3.2	Negative Effects of Fire .....	11
2.3.3	Economic Losses of Fire Hazards.....	18
2.4	Healthcare Institutions in Sri Lanka.....	20
2.5	Disaster Risk in Hospitals .....	22
2.6	Fire Hazards in Hospitals .....	23
2.6.1	Risk of Fires in Hospitals.....	23
2.6.2	Causes of Fire in Hospitals .....	24
2.6.3	Past Studies of Fire Safety in Hospitals in Sri Lanka .....	33
2.7	Disaster Risk Management.....	35
2.7.1	Introduction to Risk Management Processes .....	36
2.7.2	Plan Risk Management .....	36
2.7.3	Identifying Risks .....	37
2.7.4	Perform Risk Analysis .....	37
2.7.5	Plan Risk Responses .....	38
2.7.6	Control Risks .....	39
2.8	Frameworks, Regulations, and Codes .....	39
2.8.1	Disaster Risk Reduction Frameworks.....	39
2.8.2	Disaster Risk Reduction for Hospitals .....	40
2.8.3	Building Regulations and Codes related to Fire Safety .....	41
2.8.4	Post-Disaster Management Frameworks .....	44
2.9	Cycle of Fire Safety.....	47



2.10	Fire Safety Components .....	48
2.10.1	Fire Safety Systems.....	48
2.10.2	Building Components for Fire Safety .....	55
2.10.3	Fire Insurance.....	57
2.10.4	Fire Safety Training .....	57
2.10.5	Notices and Signs.....	60
2.10.6	Economics of Fire Safety .....	62
2.11	Involvement of the Fire Service Department.....	62
2.11.1	Contribution from the Fire Service Department .....	62
2.11.2	Fire Service Department in Sri Lanka.....	63
2.11.3	Travel from a Fire Service Department to the Location of a Fire.....	65
3	Research Methodology .....	66
3.1	Introduction .....	66
3.2	Methodology Flow Chart .....	66
4	Development of Fire Risk Management Framework Structure .....	67
5	Study of Travel from Fire Brigades to Hospitals.....	70
5.1	Introduction .....	70
5.2	Methodology .....	70
5.3	Results .....	72
6	Initial Case Studies in Hospitals .....	75
6.1	Introduction .....	75
6.2	Methodology .....	75
6.3	Criteria of the assessment form.....	76
6.4	Data Collection.....	78
6.5	Results .....	80
7	Fire Risk Assessment Tool for Hospitals.....	84

7.1	Development of the FRAT .....	84
7.1.1	Design and Construction .....	89
7.1.2	Operation and Maintenance .....	94
7.1.3	Fire Hazard Management .....	101
7.2	Application of the FRAT.....	105
7.2.1	Application in Private-Owned Hospitals .....	106
7.2.2	Application in Government-Owned Hospitals.....	113
7.2.3	Comparison of the Assessment Results between Privately-Owned and Government-Owned Hospitals.....	119
7.3	Applicability of the FRAT .....	121
8	Survey on Preparedness of Staff of Privately-Owned Hospitals in the Event of a Fire	122
8.1	Introduction .....	122
8.2	Methodology .....	122
8.2.1	Structure of the Survey .....	122
8.2.2	Choosing the Sample Set .....	122
8.3	Demography of the Responders .....	123
8.4	Results of the Questionnaire .....	126
9	Development of the Post-Disaster Activity List .....	129
9.1	Structure of the Activity List.....	129
9.2	Compilation of Post-Disaster Activities.....	129
9.2.1	People.....	130
9.2.2	Buildings and Critical Infrastructure Systems .....	131
9.2.3	Hospital Equipment .....	132
9.2.4	Hospital Material Stores .....	132
9.2.5	Post-Fire Managerial and Administrative Work.....	133

9.3	Summarization of the Proposed Activity List .....	134
9.4	Validation of the Activity List .....	140
9.4.1	Method of Validation .....	140
9.4.2	Reliability of the Data .....	141
9.4.3	Results of Validation Process .....	141
9.4.4	Discussion .....	144
10	Conclusions and Recommendations .....	146
10.1	Concluding Remarks .....	146
10.2	Recommendations.....	148
10.3	Future Work.....	150
11	Reference List .....	151
	Appendix I : Assessment of Hospital A.....	164
	Appendix II : Assessment of Hospital B.....	171
	Appendix III : Assessment of Hospital C .....	178
	Appendix IV : Assessment of DH Q.....	185
	Appendix V : Assessment of BH U .....	192
	Appendix VI : Assessment of DGH S .....	199
	Appendix VII : Questionnaire Form for Hospital Staff .....	206
	Appendix VIII : Conference Paper, Moratuwa Engineering Research Conference, July 2019.....	211
	Appendix IX : Conference Paper, International Conference on Structural Engineering and Construction Management, December 2019.....	225
	Appendix X : Conference Paper, International Conference on Sustainable Built Environment, December 2020 .....	238

## List of Figures

Figure 1: Number of disasters in 2017 by continent and top countries .....	2
Figure 2: Occurrence by disaster type: 2017 compared to 2007-2016 .....	2
Figure 3: Number of deaths by disaster type: 2017 compared to 2007-2016 .....	3
Figure 4: Selection of fire hazards .....	4
Figure 5: Number of records of disasters in Sri Lanka (2008 January – 2020 April) .	9
Figure 6: Fire Tetrahedron .....	10
Figure 7: Phases in the development of a fire .....	11
Figure 8: Breakdown of fire-related losses .....	12
Figure 9: Gases in smoke .....	13
Figure 10: Fire incidents in Sri Lanka (2009-2019) .....	15
Figure 11: Deaths due to fire incidents in Sri Lanka (2009-2019) .....	15
Figure 12: Houses destroyed due to fire incidents in Sri Lanka (2009-2019) .....	16
Figure 13: Houses damaged due to fire incidents in Sri Lanka (2009-2019) .....	17
Figure 14: Reported statistics of fire hazards.....	18
Figure 15: Different types of hospital types in Sri Lanka.....	20
Figure 16: Causes of fire in healthcare facilities in the USA.....	25
Figure 17: Causes of fires in Dutch healthcare institutions (2004-2013) .....	25
Figure 18: Countrywise distribution of the sample set .....	30
Figure 19: Time distribution of the sample set .....	31
Figure 20: Distribution of cause of fire in sample set.....	31
Figure 21: Process of planning risk responses .....	38
Figure 22: Cycle of fire safety .....	47
Figure 23: Manual call point.....	51
Figure 24: Smoke detector .....	51
Figure 25: Heat detector.....	51
Figure 26: Fire alarm sounder.....	51
Figure 27: Sprinkler head.....	53
Figure 28: Water hose reel.....	54
Figure 29: External fire hydrant.....	55
Figure 30: Diagram of a fire door .....	56

Figure 31: An example of a smoke-stop lobby .....	57
Figure 32: Influence of trained staff during evacuation.....	59
Figure 33: Fire action notice .....	61
Figure 34: Fire door notice .....	61
Figure 35: Emergency fire exit sign.....	61
Figure 36: Fire extinguisher instruction notice .....	62
Figure 37: Hierarchy of officials in fire service department in Sri Lanka.....	64
Figure 38: Fire stations in Sri Lanka.....	64
Figure 39: Fire stations in Colombo district .....	65
Figure 40: Research methodology flow chart.....	66
Figure 41: Structure of risk considering fire hazards.....	67
Figure 42: FRMF Structure.....	69
Figure 43: Path of Colombo Fire Service Department to NH Sri Lanka.....	71
Figure 44: Path of Gampaha Fire Service Department to DGH Gampaha.....	71
Figure 45: Path of Dehiwala Fire Service Department to TH Kalubowila.....	72
Figure 46: Path of Mawanella Fire Service Department to TH Kegalle.....	72
Figure 47: Average speed variations across the 24-hour time period.....	73
Figure 48: BH P - Manifold room in safe conditions .....	78
Figure 49: BH P - Abandoned incinerator in unsafe conditions .....	78
Figure 50: BH P - Improper waste management.....	78
Figure 51: DGH S - Systematic storage of waste until collection .....	78
Figure 52: DGH S - Electrical wiring in unsafe conditions.....	79
Figure 53: DH Q - Flammable materials stored next to kitchen gas.....	79
Figure 54: DGH S - Emergency evacuation notices in the buildings .....	79
Figure 55: BH U - Safe storage of medical gas .....	79
Figure 56: Fire safety preparedness of hospitals surveyed .....	83
Figure 57: Cross-section of hospital staff involved in FHM discussion.....	105
Figure 58: Assessment result summary of Hospital A.....	106
Figure 59: Assessment result summary of Hospital B.....	107
Figure 60: Assessment result summary of Hospital C.....	108
Figure 61: Assessment result summary of DH Q .....	113
Figure 62: Assessment result summary of BH U.....	114

Figure 63: Assessment result summary of DGH S .....	115
Figure 64: Job position distribution of responders .....	124
Figure 65: Gender distribution of responders .....	124
Figure 66: Age distribution of responders .....	125
Figure 67: Number of years responders had worked in the current hospital .....	125
Figure 68: Fire safety related training of responders .....	126
Figure 69: Self-evaluation of responders regarding their preparedness .....	128
Figure 70: Variation of the impact of fire with time.....	136
Figure 71: Activity categorization according to the impact of fire on people .....	137
Figure 72: Activity sequence for material stores in the fire-affected area.....	137
Figure 73: Activity sequence for buildings and critical infrastructure in the fire-affected area .....	138
Figure 74: Activity sequence for equipment in the fire-affected area .....	139
Figure 75: Fields of expertise of the experts.....	140
Figure 76: Level of agreement for post-disaster activities for people .....	142
Figure 77: Level of agreement for post-disaster activities for buildings and critical infrastructure .....	143
Figure 78: Level of agreement for post-disaster activities for hospital equipment .	143
Figure 79: Level of agreement for post-disaster activities for hospital materials....	143
Figure 80: Level of agreement for post-disaster activities for post-disaster administrative and managerial work .....	144
Figure 81: Hospital A -Design and construction assessment.....	166
Figure 82: Hospital A - Operation and maintenance assessment.....	168
Figure 83: Hospital A - Fire hazard management assessment.....	170
Figure 84: Hospital B - Design and construction assessment.....	173
Figure 85: Hospital B - Operation and maintenance assesment .....	175
Figure 86: Hospital B – Fire hazard management assessment .....	177
Figure 87: Hospital C - Design and construction assessment.....	179
Figure 88: Hospital C – Operation and maintenance assessment .....	182
Figure 89: Hospital C - Fire hazard management assessment .....	184
Figure 90: DH Q - Design and construction assessment .....	186
Figure 91: DH Q - Operation and maintenance assessment .....	189

Figure 92: DH Q - Fire hazard management assessment.....	191
Figure 93: BH U - Design and construction assessment.....	193
Figure 94: BH U - Operation and maintenance assessment .....	196
Figure 95: BH U - Fire hazard management assessment.....	198
Figure 96: DGH S – Design and construction assessment .....	200
Figure 97: DGH S - Operation and maintenance assessment .....	203
Figure 98: DGH S - -Fire hazard management assessment .....	205

## List of Tables

Table 1: Types of government hospitals in Sri Lanka and the units in them.....	21
Table 2: Details of hospital fires in the sample.....	27
Table 3: Tabulation of causes of fire countrywise.....	32
Table 4: Results of fire safety performance by Gunathilaka (2018).....	34
Table 5: Assessment of fire protection systems using HSI guide.....	34
Table 6: Maximum coverage area of and spacing between sprinkler heads.....	53
Table 7: Choosing fire extinguisher type.....	54
Table 8: Travel time data from fire service departments to hospitals.....	73
Table 9: Distance between the hospitals and their nearest fire service station.....	80
Table 10: Assessment results of hospitals surveyed.....	80
Table 11: FRAT Module - DC, Submodule - Means of escape.....	89
Table 12: FRAT Module - DC, Submodule - Fire hazard prevention.....	91
Table 13: FRAT Module - DC, Submodule - Accessibility to the fire brigade.....	93
Table 14: FRAT Module – OM, Submodule - Means of escape.....	94
Table 15: FRAT Module – OM, Submodule - Fire detection and alarm systems.....	96
Table 16: FRAT Module – OM, Submodule - Active fire protection systems.....	97
Table 17: FRAT Module – OM, Submodule -- Fire hazard prevention.....	99
Table 18: FRAT Module – OM, Submodule - Firefighting.....	100
Table 19: FRAT Module – FHM, Submodule - Disaster planning.....	101
Table 20: FRAT Module – FHM, Submodule - Staff training.....	103
Table 21: FRAT Module–FHM, Submodule-Inspection, maintenance, and testing.....	104
Table 22: Post-disaster activities to be conducted in a hospital after a fire.....	134
Table 23: Results obtained from IBM SPSS 26 software.....	141
Table 24: Hospital A - Design and construction assessment.....	164
Table 25: Hospital A – Operation and maintenance assessment.....	166
Table 26: Hospital A - Fire hazard management assessment.....	169
Table 27: Hospital B - Design and construction assessment.....	171
Table 28: Hospital B - Operation and maintenance assesment.....	173
Table 29: Hospital B – Fire hazard management assessment.....	176
Table 30: Hospital C - Design and construction assessment.....	178



Table 31: Hospital C – Operation and maintenance assessment .....	180
Table 32: Hospital C - Fire hazard management assessment.....	183
Table 33: DH Q - Design and construction assessment.....	185
Table 34: DH Q - Operation and maintenance assessment.....	187
Table 35: DH Q - Fire hazard management assessment .....	190
Table 36: BH U - Design and construction assesment.....	192
Table 37: BH U - Operation and maintenance assessment.....	194
Table 38: BH U - Fire hazard management assessment .....	197
Table 39: DGH Matara - Design and construction assessment .....	199
Table 40: DGH S - Operation and maintenance assessment .....	201
Table 41: DGH S - Fire hazard management assessment.....	204

## **List of Abbreviations**

BBB	Build Back Better
BH	Base Hospital
DC	Design and Construction
DGH	District General Hospital
DH	Divisional Hospital
DRP	Disaster Recovery Plan
DRR	Disaster Risk Reduction
EEP	Emergency Evacuation Procedures
ERT	Emergency Response Team
FAP	Fire Action Plan
FC	Fire Commander
FEMA	Federal Emergency Management Agency
FHM	Fire Hazard Management
FRAT	Fire Risk Assessment Tool
FRMF	Fire Risk Management Framework
FRS	Fire and Rescue Services
FSC	Fire and Safety Check
GDP	Gross Domestic Product
HDMP	Hospital Disaster Management Plan
HSI	Hospital Safety Index
IRS	Incident Reporting System
NGDP	National Gross Domestic Product
NH	National Hospital

OM	Operation and Maintenance
PMCU	Primary Medical Care Unit
TH	Teaching Hospital
UNISDR	United Nations International Strategy for Disaster Reduction