Simplified way to Cooling Load Capacity of a Room

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ABSTRACT: *In present days Air conditioning machine is the main part of life, but to choose the best air conditioning machine is need to installed and to find the thermal and cooling load capacity of air conditioner in tons. In any organization majority of electrical energy is being consumed by the Heating Ventilation and Air Conditioning (HVAC). To calculate the optimum rate of energy at which heat need to be rejected from dining room to establish thermal equilibrium and maintain inside comfort zone. The aim of this research study is to calculate the cooling load capacity of dining room of GJUS&T, Hisar (HR) and to propose the ways which could save the electrical energy.*

Key Words: *CLTD, HVAC, Human Comfort and Air Conditioning*

1. INTRODUCTION

India is the third largest consumer of electrical energy after USA and China. Energy audit is an essential factor which defines the ways to conserve and minimize the use of electric energy which helps in controlling energy cost. To optimize the electrical energy HVAC is the main active target of energy expenditure for the purpose to improve the power factor, to minimize energy cost and to reduce the maximum power of demand rate. Because maximum electricity used in any building through HVAC system is 40% of total electricity consumption [6].

HVAC system is Heating, Ventilation and Air Conditioning system. In any particular space or area three controlling factors required which are responsible as per HVAC which are humidity, temperature and pressure of air flow [4]. HVAC works on primarily works on design of mechanical system and control of other environment factor i.e. humidity level and air distribution rate for human comfort at any place. This HVACmechanical system design is an shown to take control over the environmental conditions inside the space we work [1,5].

Sen et al. 2016 This case study describe the 60 seated classroom which are situated in RPS College of Engineering and Technology, Haryana, India. Used CLTD (Cooling load temperature difference) method was developed by ASHRAE in order to determine the cooling load of a classroom in an institute. Sensible heat, latent heat which absorb due to glass, walls, roof, infiltration and internal heat factors are considered and proposed to 7.96 TR (Ton of Refrigeration) air conditioner is required[1].

Yadav et al. 2016 This case study describe the Lecture hall, Parthivi Building Institute, Chhatisgarh, India to calculating the cooling load by hand calculation as per ASHRAE. Solar heat which gain from glass, walls, roof and heat gain from appliances, occupancy, infiltration and ventilation, dehumidified air quantity factors involved to estimate the cooling load of the air conditioning units of the corridors which were used as part of the address lobbies to effectively remove life forms, cleaning and sediment from the air of a smaller scale[2].

Grinbergs et al. 2013 This case study describe the Industrial plants, Latvia. Energy consumption equipment through Industrial plants i.e.computers, machines Infiltration and ex-filtration, relative humidity factors considered using industrial energy audit techniques used. Industrial energy audit define is quite new using world experience and standards, so projects where energy savings surpass 70 percent of total energy demand have been created[3].

Verma et al. 2016 This case study describe the Hotel building and Hospital using Automation service and Networking technology implement. And to designed the hotel building automation in conceptual way as a goal of better comfort providing to guests with maximum energy efficiency[4].

Yadav et al. 2017 This case study describe the 30 seated Tutorial room, IMS Engineering College, Ghaziabad, India. Solar heat gain and transmission heat gain due to glass, walls, roof and infiltration factors include using CLTD by MS-Excel program and proposed to 3.558 TR (Ton of Refrigeration) air conditioner is required[5].

Raja et al. 2017 This case study describe the E and E Engineering, MIT Manipal using Energy audit on scenario, performance and conservation technique. Lighting and HVAC control parameters i.e. Arduino UNO Microcontroller implement and used HVAC systems, roughly energy is consumed 40% and energy is consumed for lighting systems by 15%[6].

2. METHODOLOGY USED TO CALCULATION OF COOLING LOAD

To calculate the exact load requirement of the closed space for the use of the ACs in that defined space. The sensors and arduino were used to calculate the load requirement of air conditioning. The book of Refrigeration and air conditioning by C.P. Arora to take the coefficient value and calculate cooling load capacity of air conditioning. All steps of cooling load calculation are shown in figure 1.

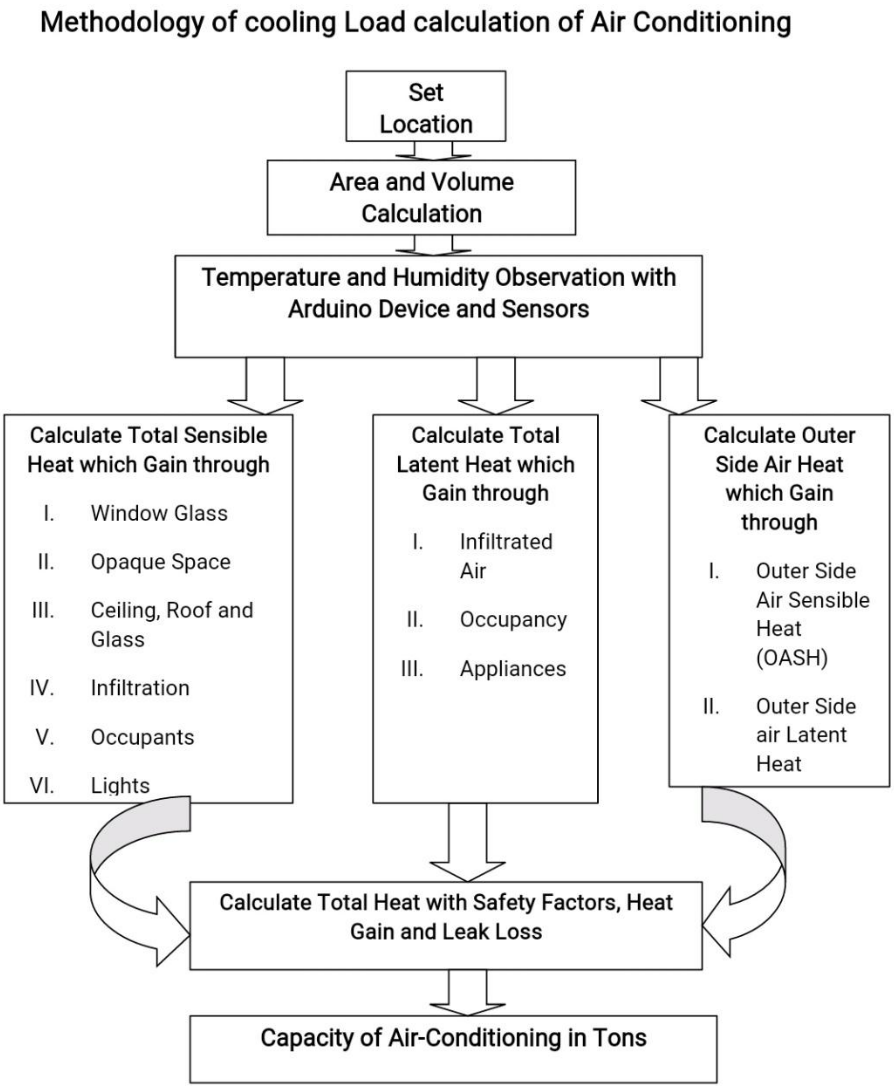


Figure – 1 Cooling Load Calculation Methodology

The cooling load may be defined as the amount of heat is required to be thrown away through the space to meet the desired temperature range and the required relative humidity for maintaining the comfort level. This load consists of two main categories:

(a) Internal load
(b) External load

2.1 Internal and External Heat Gain: The internal heat occurs from the sources like the people present in the room, the lights that being used in the room and the other electric equipments present in the surrounding. The external heat occurs from the sources like walls, windows, doors, ceilings and from the ground.

2.2 Sensible Heat Gain from Opaque Space: Sensible heat gain consists of the heat from the factors like windows, doors, ceilings and other external heat gain factors. The sensible heat gain can be done from all the modes of heat i.e. conduction, convection and radiation. This could be calculated using the formula:

Q = UA(CLTD)

where,

Q = Total sensible heat gain

U = Overall transfer of heat coefficient (W/m2-°C)

A = Surface area (m2)

CLTD = Cooling Load Temperature Difference (°C)

2.3 Heat Gain through Glass: Radiation is the process by which the heat is gained through glass. Heat could be in the form of direct sunlight or through the reflection of sunlight from the other objects. The factors on which the heat transmission through glass depends are the physical and chemical composition of the glass and the wavelength of the radiation. This could be calculated using the formula:

Q = UA(CLTD)

By solar radiation:

$$Q = A * SHGF(max) * SC * CLF$$

where,

SHGF = maximum solar heat gain factor (W/m2)

SC = shading coefficient

CLF = Cooling load factor.

2.4 Heat Gain from Occupants: In a cooled space the human body consists of the latent heat nd sensible heat of cooling load. In a room with an AC due the temperature difference between the room air and the human body the sensible heat load is given out and the total amount of the heat load totally depends on the activity of the human body. This gain increases with the increase in the human activity. This gain could be calculated using two equations:

Sensible heat gain from occupants:

$$Q(s, person) = q\ (s, person) * N * CLF$$

Latent heat gain from occupants:

$$Q(l, person) = q\ (l, person) * N$$

Where,

Q(s, person) = sensible heat gain / person (W)

Q(l, person) = latent heat gain / person (W)

N = number of the people present in the room

CLF = cooling load factor

2.5 Heat Gain from Lighting Equipments: The amount of the electric power generated by lighting is equal to the amount of the sensible heat generated by the lighting equipments. The total sensible heat which is gained from the lighting equipments depends on the various factors such as allowance factor, use factor and the rating of light in watts. It is calculated using the following formula:

$$Q\ (light) = total\ wattage\ of\ light * allowance\ factor * use\ factor$$

The allowance factor is taken only in the case of florescent lights and is usually taken as

1.25. The use factor is the ratio of the wattage which is in use to the actual wattage installed.

2.6 Heat Gain from Electrical Equipments:

The heat gained from the equipments like refrigerators, AC, Coolers, Fans, printers, fax, and computers fall under this category. This is a very similar process with the heat gain from lighting. It is calculated by:

$$Q(equipment) = Total\ wattage\ of\ equipment * use\ factor * CLF$$

2.7 Total Loads: The total heat load may be defined as the sum of the total room latent heat gain and the total room sensible heat gain.

$$RTH = RLH + RSH$$

Where,

RTH= Room Total Heat

RLH= Room Latent Heat

RSH= Room Sensible Heat

2.8 Total Room Sensible Heat Gain: It is the sum of all type of the sensible heat present in the focused region or space.

2.9 Total Room Latent Heat Gain: It is the sum of the all type of the latent heat present in the focused region or space.

2.10 Room Sensible Heat Factor: Room sensible heat factor is defined as the ratio of the room sensible heat to the total room heat. Mathematically,

$$RSHF = \frac{RSH}{RLH + RSH} = \frac{RSH}{RTH}$$

2.11 Total Load in Tons: All the above values calculated are in Watts and we need to convert all these into tons by using:

$$Total\ load\ in\ tons = \frac{total\ load\ in\ watts}{35000}$$

2.12 Selection of AC: After calculating the load requirement we need to select the type of A.C. according to the suitability of the confined region.

Different Types of Air Conditioning System

There are certain factors that need to be considered while selecting right type of air conditioner such as the area to be cooled, the total heat energy generated inside the room or building etc. An expert would consider all the affecting parameters and factors and then give suggestion the most appropriate refrigeration system.

- Window Air Conditioner.
- Split Air Conditioner
- Packaged Air Conditioner
- Central Air Conditioning System

3. CALCULATION OF COOLING LOAD OF DINING ROOM

Now final step of calculation of cooling load of dining room using CLTD method is as following:

3.1 Location and Weather Conditions:: Guru Jambheshwar University of Science And Technology is located in the city of Hisar in Haryana, India Design of dining room layout is shown in figure2 which are shown the door, windows and wall facing as well as direction.

Hisar lies in the Haryana state of the country India. The city has a very continental climate which means that it is very hot in summers and extremely cold in winters. The temperature in Hisar varies from 2 deg centigrade to 45 deg centigrade. The latitude is 29.151861 and longitude is 75.721123 and average rainfall in the city is about 429mm.

Total load of cooling, ratios of sensible heat and total air dehumidify of dining room and air amounts measured using cooling load temperature difference (CLTD) methodology. Temperature humidity and air flow of reading is find out by sensing device with the help of Arduino and computer system device as per the methodology used. Cooling load description of dining room Summer (May month) and Monsoon (July month) is shown below.

Area and volume of Space (Dining Room) calculation

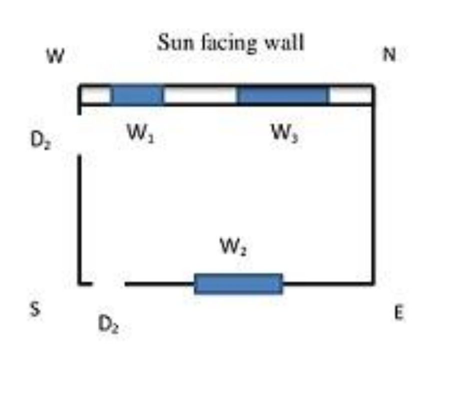
Length of Dining room (L) = 7.62 m	
Width of Dining room (W) = 4.57 m	
Height of Dining room (H) = 3.73 m	
Area of window glass (W1) = 0.762*1.676 = 1.277 m2	
Area of window glass (W2) = 1.524*1.676 = 2.554 m2	
Area of window glass (W3) = 2.13*1.676 = 3.569 m2 Area of door (D) = 1.21*2.28 = 2.758 m2	

Figure – 2 Design of Dining Room

Table –1 Area and volume of Space (Dining Room) calculation

Area of wall (NW) = LH-W1-W3 = (7.62*3.73)-1.277-3.569 = 23.576m2 sun facing wall

Area of wall (NE) = WH = 4.57*3.73 = 17.04m2

Area of wall (ES) = LH- W2-D = (7.62*3.73)-2.544-2.758 = 23.12m2

Area of wall (SW) = WH-D = (4.57*3.73)-2.758 = 14.288m2

Total area of wall = 78.024m2

Volume of Space (LWH) = 7.62*4.57*3.73 = 129.891m3

Area of Space (LW) = 7.62*4.57 = 34.823m2

Infiltrated air amount which pass through walls and windows as now =

7.62*4.57*3.73/60 = 2.164m3/min

Requirement of ventilation in 1m2 = 0.02m3/min

Total ventilation requirement in dining room = 0.02*78.024 = 1.56m3/min

3.2 Temperature and Humidity of Dining Room: Outside and inside value of temperature and humidity calculation is as following which are shown in table 2.

Temperature and Humidity of Dining Room	Summer May Month				Monsoon July Month			
Condition	**DBT**	**WBT**	**%RH**	**kg/kg**	**DBT**	**WBT**	**%RH**	**kg/kg**
Outer side	44	33	46	0.02481	37	34	84	0.03122
Inner side	24	17	50	0.00865	24	17	50	0.00866
Differences	20	-	-	0.01611	13	-	-	0.0226
Air changes unit in 1Hour	1.00		**Filtrated Air (m3/min)**				2.164	

Table –2 Temperature and Humidity of Dining Room

3.3 Heat Gain through Glass: Radiation is the process by which the heat is gained through glass. Heat could be in the form of direct sunlight or through the reflection of sunlight from the other objects. The factors on which the heat transmission through glass depends are the physical and chemical composition of the glass and the wavelength of the radiation.

In Glass, Solar Heat Gain Calculation			Summer May Month		Monsoon July Month	
Side	**Area (m2)**	**Factor (U)**	**W/m2**	**Heat (W)**	**W/m2**	**Heat (W)**
Glass (N)		0.48	129	0	136	0
Glass (N-E)		0.13	527	0	521	0
Glass (E)		0.11	631	0	618	0
Glass (S-E)		0.14	372	0	360	0
Glass (S)		0.22	129	0	129	0
Glass (S-W)		0.52	372	0	360	0
Glass (W)		0.52	631	0	618	0
Glass (N-W) (W1+W3)	4.846	0.47	527	1200.305	521	1186.640
Total				1200.305		1186.640

Table –3 Heat Gain through Glass

3.4 Solar Heat Gain from Opaque (walls and roof) Space: Sensible heat gain consists of the heat from the factors like windows, doors, ceilings and other external heat gain factors. The sensible heat gain can be done from all the modes of heat i.e. conduction, convection and radiation.

In Walls and Roof, Solar Transmission and Heat Gain Calculation			Summer May Month		Monsoon July Month	
Side	**Area (m2)**	**Factor (W/m2-DegC)**	**Temperature Difference (DegC)**	**Heat (W)**	**Temperature Difference (DegC)**	**Heat (W)**
Wall (N)		1.07	23.40	0	16.00	0
Wall (N-E)		1.07	27.25	0	20.80	0
Wall (E)		1.07	28.40	0	19.80	0
Wall (S-E)		1.07	26.00	0	18.00	0

Wall (S)		1.07	22.00	0	14.20	0
Wall (S-W)		1.07	26.00	0	17.60	0
Wall (W)		1.07	28.50	0	20.90	0
Wall (N-W)	23.576	1.07	27.20	686.156	21.20	534.798
Roof Sun		4.16	47.00	0	41.00	
Total				686.156		534.798

Table –4 Solar Heat Gain from Opaque (walls and roof) Space

3.5 Transmission Heat Gain from all glass, ceiling and roof: Sensible heat consists of the heat except from roof and walls in which heat gain can be done from all modes of heat transfer.

In All Glass, Walls and Roof; Transmission Heat Gain Calculation			**Summer May Month**		**Monsoon July Month**	
Side	**Area (m2)**	**Factor (W/m2-DegC)**	**Temperature Difference (DegC)**	**Heat (W)**	**Temperature Difference (DegC)**	**Heat (W)**
All Glass (W1+W2+W3)	7.4	5.60	20.20	837.088	13.20	547.008
Partition	78.024	1.86	14.80	2147.845	7.80	1131.972
Ceiling (L*W)	34.823	2.82	14.80	1453.373	7.80	765.967
Floor (L*W)	34.823	4.50	2.40	376.088	2.40	376.088
Total				4814.394		2821.035

Table –5 Transmission Heat Gain from all glass, ceiling and roof

3.6 Heat Gain from Infiltration:

The amount of air infiltrated through windows and walls is now =

7.62*4.57*3.73/60 = 2.164m3/min

Requirement of ventilation in 1m2 = 0.02m3/min

Total ventilation requirement in dining room = 0.02*78.024 = 1.56m3/min

Infiltration Heat Gain Calculation			**Summer May Month**		**Monsoon July Month**	
Infiltrated Air	**Bypass**	**Factor (W/m2-DegC)**	**Temperature Difference (DegC)**	**Heat (W)**	**Temperature Difference (DegC)**	**Heat (W)**
2.164	1	20.44	19.8	875.797	12.9	570.595

Table –6 Heat Gain from Infiltration

3.7 Internal Heat Gain from Occupants, Lights and other Equipments: In a cooled space the human body consists of the latent heat and sensible heat of cooling load. In a room with an AC due the temperature difference between the room air and the human body the sensible heat load is given out and the total amount of the heat load totally depends on the activity of the human body. This gain increases with the increase in the human activity.

The amount of the electric power generated by lighting is equal to the amount of the sensible heat generated by the lighting equipments. The total sensible heat which is gained from the lighting equipments depends on the various factors such as allowance factor, use factor and the rating of light in watts.

Internal Heat Gain Calculation			Summer May Month		Monsoon July Month	
Item	**Numbers**	**Factor (W/m2-DegC)**	**Temperature Difference (DegC)**	**Heat (W)**	**Temperature Difference (DegC)**	**Heat (W)**
Peoples	13	70	-	910	-	910
Lights (W/m2)	08	67	-	536	-	536
Equipment (KW)	00	00	-		-	
Total				1446		1446

Table –7 Internal Heat Gain Calculation

3.8 Total Sensible Heat of Dining Room:

Sensible Heat Gain Calculation	Summer May Month	Monsoon July Month
Palace	**Heat (W)**	**Heat (W)**
Heat Gain through Glass	1200.305	1186.640
Solar Heat Gain from Opaque (walls and roof) Space	686.156	534.798
Transmission Heat Gain from all glass, ceiling and roof	4814.394	2821.035
Heat Gain from Infiltration	875.797	570.595
Internal Heat Gain from Occupants, Lights and other Equipments	1446	1446
Subtotal Sensible Heat of Dining Room	9022.652	6559.068
Heat Gain, Leak Loss and Safety Factor (6%)	541.359	393.544
Total Sensible Heat	9564.011	6952.612

Table –8 Total Sensible Heat of Dining Room

3.9 Total Latent Heat of Dining Room:

Latent Heat Gain Calculation			Summer May Month		Monsoon July Month	
Infiltrated Air	**Bypass**	**Factor (W/m2-DegC)**	**Difference kg/kg**	**Heat (W)**	**Difference Kg/kg**	**Heat (W)**
2.164	1	50000	0.01611	1743.102	0.0226	2445.32
No. of Peoples	13	45	-	585	-	585
Appliances	-	-	-	-	-	-
Steam	-	-	-	-	-	-
Subtotal Latent Heat of Dining Room			2328.102		3030.32	
Heat Gain, Leak Loss and Safety Factor (5%)			116.405		151.516	
Total Latent Heat			2444.507		3181.836	

Table –9 Total Latent Heat of Dining Room

3.10 Outer Side Air Heat of Dining Room

Outer Side Air of Sensible Heat (OASH)						
Outer Side Air	**1-BPF**	**Factor**	**Temp Diff (DegC)**	**Heat (W)**	**Temp Diff (DegC)**	**Heat (W)**
1.56	0.88	20.44	20	561.20	13	364.78
Outer Side Air of Latent Heat (OALH)						
Outer Side Air	**1-BPF**	**Factor**	**Diff. (kg/kg)**	**Heat (W)**	**Diff. (kg/kg)**	**Heat (W)**
1.56	0.88	50000	0.01611	1105.790	0.0226	1551.264
Subtotal Outer Side Air Heat of Dining Room			1666.99		1916.044	
Heat, Leak Gain and Safety Factor (5%)			83.349		95.952	
Total Outer Side Air Heat			1750.339		2011.996	

Table –10 Outer Side Air Heat of Dining Room

3.11 Exact Thermal Load Calculation of Air conditioning:

Thermal Load Calculation	**Summer May Month**	**Monsoon July Month**
	Heat (W)	**Heat (W)**
Total Sensible Heat	9564.011	6952.612
Total Latent Heat	2444.507	3181.836
Total Outer Side Air Heat	1750.339	2011.996
Grand Total Heat	13758.857	12146.444
Tons (W/3500)	3.931	3.470

Table –11 Exact Thermal Load Calculation of Air conditioning

4. RESULTS

Exact Capacity of Thermal Load Calculation of Air conditioning in MS Excel Program: To fill the Temperature, humidity and space area, volume then to calculate the exact capacity**.** In Dining Room is to maintain the inner space temperature is 24, 25, 26.....,30 as per required as follows:

Temperature (deg C)	**Summer May Month (Tons)**	**Monsoon July Month (Tons)**
24	3.932	3.467
25	3.898	3.432
26	3.864	3.398
27	3.829	3.363
28	3.795	3.329
29	3.761	3.295
30	3.726	3.260

Table –12 Thermal Load Capacity of Air conditioning at different Temperature

5. CONCLUSIONS

- In this cooling load calculation case study Dining room of an GJUS&T University of Science and Technology, Hisar (HR) to require the 3.932 TR for summar May month and 3.467 TR for monsoon July month air conditining machine is required to maintain the inner temperature of 24degC.

- Cooling load calculating items i.e. lighting, occupancy, ventilation, infiltration and electrical equipments are easily mentioned and calculated with the help of MS Excel Program..
- There is very less work done for building design as per sunlight factor and air direction factor, due to which energy loss in HVAC is affected.
- As the development is growing in the field of infrastructure and buildings, the demand of HVAC will be growing in the future due to this growth.

6. ACKNOWLEDGEMENT

I **(Sumit Singla)** student of M. Tech in Mechanical Engineering department express my deep sense of gratitude to my esteemed guide **Dr. Pankaj Khatak** (Associate Professor and Chairman) Department of **Mechanical Engineering** and **Dr. Sumit Saroha (**Assistant Professor Electrical Engineering) Department of **Printing Technology** of **Guru Jambheshwar University of Science & Technology, Hisar,** for their erudite and prolific guidance and critical appraisal, constant supervision and valuable help during the course of present research work In- fact their keen interest in the research work gave inspiration and generated confidence in me to complete the research work.

I would also like to express my special thanks to my team member **Rupender Singh**, **Nitish Chhabra**, **Manish Kumar** and **Vikash** student of Mechanical Engineering Deptt. in B.Tech for their help in practical work during the research work.

Words are insufficient to express the co-operation, love, blessings and affection that I received from my family members.

Last but not least, my sincere acknowledgement is to various authors whose works have been consulted and cited in present research work.

And I would like to thanks my parents for their unconditional support, love and affection. Their encouragement and never ending kindness made everything easier to achieve.

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