



Degree of Master of Philosophy

Investigation and Development of Fuzzy
Logic Based Analytics for Data
Warehousing

PARANA PALLIYA GURUGE DINESH ASANKA
158062B

Supervisor(s):

Dr. Amal Shehan Perera

2021-02-19

Department of Computer Science and Engineering
Faculty of Engineering

UNIVERSITY OF MORATUWA - SRI LANKA

Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree 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 acknowledgement is made in the text.

Further, I hereby grant to 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:

PPG Dinesh Asanka

The above candidate has carried out research for the MPhil Dissertation under my supervision.

Signature of the Supervisor:.....

Date:

Dr. Amal Shehan Perera

Acknowledgments

First, I express my sincere gratitude to my supervisor Dr. Amal Shehan Perera for guiding me throughout the project. Despite his busy schedule, he has given his fullest corporation whenever I wanted his assistance. I would also like to extend my appreciation to the panel members Dr. Dilum Bandara and Dr. Lochandaka Ranathunga for their valuable advice given to me throughout this project lasting more than four years. In addition, I am thankful to Prof. Sanath Jayasena for the valuable ideas given at the initial research stage. These ideas helped me to a great extent.

My loving parents and my wife always encouraged me towards higher studies. Especially, my wife and my two children made many sacrifices. I admit words cannot describe the sacrifices made. Anyhow, I would be failing in my duty if I leave them out of the honors.

This research is on data warehouse and I thank the three companies that contributed with their experience in data warehousing. The first data warehouse where I got the necessary experience was Ocean Software. There, I had an opportunity to work in the UK as well and got the most experience. At Pearson, I was able to implement some of the concepts that I learned importantly, administration and the configuration aspects of the data warehouse. At Virtusa, I was able to work on end-to-end aspects of data warehouse starting from the requirement gathering to deployment including the non-functional requirements of data warehouse. I deeply appreciate the kindness shown and thank all the co-workers and the management of these organizations.

Jagath Robotics (Pvt) Ltd provided me the data set which was used in this research as a proof of concept. Data gathering is a challenging task in any research. Collecting data from a reputed source helped me to proceed with the research.

I was awarded the Microsoft Most Valuable Professional by Microsoft. This allows me to gain experience with the Microsoft BI platform. The experience helped me a lot for this research. Hence, I thank Microsoft for awarding me the MVP award for 11 consecutive years.

I was fortunate enough for opportunities to lecture on data warehouse at different universities and institutions in Sri Lanka like the Sri Lanka Institute of Information Technology (SLIIT), Institute of Information Technology (IIT), Kothalawala Defence University (KDU), University of Ruhuna, University of Kelaniya, and University of UVA Wellassa. These institutions

provided me with the opportunity to lecture and these lectures helped enable me with the necessary knowledge in the area of the data warehouse. I also had the opportunity to supervise many data warehousing projects at MSc and BSc levels. This was a great opportunity. I was able to present data warehouse related sessions at places such as SQL Saturday, Colombo Big Data User Group, Sri Lanka Association of Artificial Intelligence (SLAAI), SQL Server Sri Lanka User Group (SSSLUG), Sri Lanka Azure Road Show, Colombo Dev Day, Malaysia TechInsights which allowed me to gain and present knowledge with data warehouse. I thank the organizers of these user groups for inviting me to these events so that I was able to gain knowledge in the data warehousing.

I pay my gratitude to all the teachers who taught me starting from my first school to B.Sc, MBA and MSc degrees. They gave me a sound base for many technical concepts and research methodologies.

Abstract

Data warehouse is a widely used technology that provides the employees who take strategic decisions within an enterprise with access to any level of required data. Historically, data warehouses were built on crisp values with a key assumption that one attribute value falls into one nominal value. Fuzzy Logic can be built into the data warehouse by treating the dimension value as weightages of different labels. However, in most of the attempts to implement a fuzzy data warehouse, they were limited and non-comprehensive in the implementation when considering end to end aspects of the data warehouse.

Using fuzzy techniques, it is possible to represent fuzzy conceptual information in the original domain, that would lead to better analysis. In this research, different types of fuzzy membership functions are defined using different techniques and data warehouse facts and dimensions are designed accordingly. There can be multiple fuzzy functions for one dimension as well as for one fact table depending on the business domain. Apart from defining fuzzy membership function using data-driven methods, there are other approaches of defining fuzzy membership functions such as a derived method where multiple fuzzy memberships are combined to define several fuzzy membership functions. In the literature reviewed, concepts like ETL and OLAP cube were found to be discussed in a limited manner. Non-function techniques are also identified and addressed in the means of validation, configuration, performance, security, scalability in order to make better usability of the fuzzy data warehouse.

The scope of this research revolves around end-to-end features of fuzzy data warehousing starting from data extraction and transformation to data warehouse modeling. Implementing a fuzzy data warehouse, helps to enable users with better analyses. To verify whether the proposed fuzzy data warehouse can be applied, a feasibility study is carried out for the domains in which fuzzy data warehousing can be implemented. Concepts related to the outcome from this research are verified with the use of a Sri Lankan plantation data set for four years. The results show that concepts introduced by this research can be implemented in realistic scenarios.

Key Words: Data Warehouse, Fuzzy Logic, Fuzzy Membership Function, ETL, OLAP

TABLE OF CONTENTS

Acknowledgments.....	ii
Abstract.....	iv
Abbreviations.....	2
Chapter 1 INTRODUCTION.....	4
1.1 Prolegomena	4
1.2 Background and Motivations	5
1.3 Philosophical Aspect.....	6
1.4 Problem in Brief.....	7
1.5 Aims and Objectives	8
1.6 Areas of Concern	10
1.7 Summary	11
Chapter 2 FUZZY DATA WAREHOUSE – STATE-OF-THE-ART.....	12
2.1 Introduction.....	12
2.2 Data Warehouse	13
2.3 Extract Transform and Load	21
2.4 Fuzzy Database Modelling.....	22
2.5 Fuzzy Data Warehouse Modelling.....	26
2.6 Fuzzy Logic	32
2.7 De-Fuzzification and Fuzzy Rules.....	37
2.8 OLAP Cube.....	39
2.9 Fuzzy OLAP Cube.....	46
2.10 Summary	47
Chapter 3 RESEARCH METHODOLOGY	49
3.1 Introduction.....	49
3.2 Constructive Design Research	49
3.3 Input-Process-Output	49
3.4 Sub-Tasks.....	52

3.5	Data Set.....	54
3.6	Resources Required	58
3.7	Summary	58
Chapter 4.....		60
FEASIBILITY STUDY FOR FUZZY DATA WAREHOURE IMPLEMENTATION		60
4.1	Introduction.....	60
4.2	Data Warehouse Domains.....	60
4.3	Retail Sales.....	61
4.4	Inventory	62
4.5	Order Management	65
4.6	Customer Relationship Management	65
4.7	Human Resource Management	68
4.8	Financial Services	70
4.9	Healthcare	71
4.10	Summary	73
Chapter 5 FUZZY MEMBERSHIP FUNCTIONS.....		76
5.1	Introduction.....	76
5.2	Box Plot Method	76
5.3	Five State Fuzzy Membership Function	77
5.4	Three State Fuzzy Membership Function	79
5.5	Implementation using Box-Plot Method.....	81
5.6	Evaluation	84
5.7	Validation and Error Correction	88
5.8	Properties of Fuzzy Membership Functions	90
5.9	Subjective Fuzzy Membership Function.....	92
5.10	Hybrid Fuzzy Membership Function	97
5.11	Derived Fuzzy Membership Function.....	97
5.12	Linguistic Variables for Fuzzy Membership Function	105

5.13	Integration of Fuzzy Membership Functions	114
5.14	Summary	116
Chapter 6 FACT AND DIMENSION TABLES DESIGN		118
6.1	Introduction.....	118
6.2	Standard Implementation of Data Warehouse	119
6.3	Fuzzy Implementation for Range Values.....	122
6.4	Evaluation	127
6.5	Different Types of Dimensions.....	129
6.6	Fuzzy Configuration for Type 2 Slowly Changing Dimension	131
6.7	Hierarchical Categorization Dimensions	133
6.8	Fuzzy Membership Function for Fuzzy Categorization.....	140
6.9	Subjective Method	140
6.10	Normal Horizontal Method.....	141
6.11	Ranked Based Horizontal Method	144
6.12	Pairwise Comparison Method.....	146
6.13	Evaluation of Fuzzy Categorization.....	148
6.14	Summary	150
Chapter 7 FUZZY EXTRACT-TRANSFORM-LOAD.....		152
7.1	Introduction.....	152
7.2	Transformation Tasks	152
7.3	Fuzzy Dimensions.....	153
7.4	Fuzzy Fact Measures.....	156
7.5	Fuzzy Transformation Tasks.....	156
7.6	Summary	157
Chapter 8 FUZZY OLAP CUBE		158
8.1	Introduction.....	158
8.2	Classical OLAP Cube	158
8.3	Basic Fuzzy OLAP Cubes.....	161

8.4	Slicing.....	166
8.5	Dicing.....	168
8.6	Roll-up	169
8.7	Drill-Down.....	170
8.8	Summary	170
Chapter 9 IMPLEMENTATION OF FUZZY DATA WAREHOUSE		172
9.1	Introduction.....	172
9.2	Validation.....	172
9.3	Configuration	173
9.4	Performance	177
9.5	Security	179
9.6	Scalability	180
9.7	Summary	180
Chapter 10 CONCLUSION		182
10.1	Introduction.....	182
10.2	Research Work.....	182
10.3	Future Work	184
References.....		185
Bibliography		193
Appendix A:	Fact Tables	194
Appendix B:	Dimension Tables	199
Appendix C:	Date Dimension.....	203
Appendix D:	Types of Fuzzy Membership Functions.....	206
Appendix E:	Operations in Fuzzy Sets.....	212
Appendix F:	Fuzzy Membership Function Determination	213
Appendix G:	Features of Fuzzy Membership Functions	214
Appendix H:	Computing with Linguistic Variables	216
Appendix J:	Tools Used for the Research	219

Appendix K:	Spider Diagram of Fuzzy Data Warehouse Research	222
Appendix L:	Sample R Script for Model Box Plot	223
Appendix M:	NFR Lists	228
Appendix N:	Script to Generate Fuzzy Contribution	230
Appendix O:	Script to Generate Fuzzy Contributions for Linguistic Functions	231
Appendix P:	Scripts to Evaluate Fuzzy State Contributions	234
Appendix Q:	Scripts to List Properties of Function Membership	236
Appendix R:	Scripts to Generate Membership Function for Subjective Method.....	238
Appendix S:	Performance of Execution of Fuzzy Configuration Steps.....	243
Appendix T:	Proof of Summation of Derived Membership Contribution Value Equal to One...	244
Appendix U:	Script to Calculate of Derived Membership Function Contribution	245
Appendix V:	Calculation of Derived Membership Function.....	246
Appendix W:	Scripts for Calculation of Fuzzy Categorization	248
Appendix X:	Subsystems of ETL	250
Appendix Y:	Scripts for Fuzzy OLAP Cube	252
Appendix Z:	Design Patterns for Data Warehouse	255
Appendix AA:	Publications	258
Appendix BB:	Citations	259

LIST OF FIGURES

Figure 2-1: Data Warehouse Reference Architecture	15
Figure 2-2: Different Data Warehouse Environments	16
Figure 2-3: Implementation of Fuzzy ETL	22
Figure 2-4: Fuzzy Data Types.....	24
Figure 2-5: The Fuzzy Customer Age Dimension Report	27
Figure 2-6: The Fuzzy Data Warehouse Schema Comprising Fuzzy Hierarchies.....	29
Figure 2-7: Proposed Architecture for Fuzzy Multidimensional model for OLAP	30
Figure 2-8: Fuzzy Inference System for Disease Diagnosis	35
Figure 2-9: Fuzzy Rules.....	38
Figure 2-10: Largest of Maximum De-fuzzification of the Fuzzy Set.....	39
Figure 2-11: Mapping of Star Schema to OLAP Cube	42
Figure 2-12: Slicing and Dicing of OLAP Cube.....	43
Figure 2-13: OLAP Operations in Multidimensional Cubes	44
Figure 2-14: Lattice Structure of Cuboids	45
Figure 3-1: Spider Diagram for Fuzzy Data Warehouse	50
Figure 3-2: Input-Process-Output for Fuzzy Data Warehouse	51
Figure 3-3: Distribution of Transactions Year Wise.....	55
Figure 3-4: Distribution of Transactions Division Wise.....	56
Figure 3-5: Distribution of Transactions Work Code Wise	57
Figure 3-6: Employee Distribution for Gender.....	57
Figure 4-1: Star Schema Design for Inventory	63
Figure 4-2: Data Model for Inventory Receipt Accumulating Fact Table	64
Figure 4-3: County Demographics Outtrigger Dimension.....	66
Figure 4-4: Identify Customer Relationship using Mamdani de-fuzzification Method.....	67
Figure 4-5: Extended Customer Dimension.....	68
Figure 4-6: Employee Skill Group Dimension	69
Figure 4-7: Data Model for Employee Headcount Snapshot Fact Table	69

Figure 4-8: Data Model for Monthly Account Snapshot Fact Table	70
Figure 4-9: Data Model for Monthly Checking Snapshot Fact Table	71
Figure 4-10: Data Model for Diagnosis Fact Table	72
Figure 4-11: Data Model for Diagnosis Group Dimension Table	72
Figure 5-1: Parameters of Box Plot.....	77
Figure 5-2: Five State Fuzzy Membership Function.....	78
Figure 5-3: Three State Fuzzy Membership Function	80
Figure 5-4: Range of Box Plots for Age Year Wise	82
Figure 5-5: Range of Box Plots for Age Year Wise	83
Figure 5-6: Steps for Box Plot Method.....	84
Figure 5-7: Fuzzy Membership Function for Age	85
Figure 5-8: Comparison of Fuzzy Membership Function for Age with Crisp Data Sets.....	86
Figure 5-9: Range of Box Plots for Experience	87
Figure 5-10: Range of Box Plots for Permanent Wise.....	87
Figure 5-11: Membership Function for Age Before the Error Correction	89
Figure 5-12: Modified Fuzzy Membership Function after Error Correction.....	90
Figure 5-13: Properties of Fuzzy Membership Function for Age.....	91
Figure 5-14: Properties of membership Function for Experience (5 State)	92
Figure 5-15: Fuzzy Membership Function for Experience	93
Figure 5-16: Fuzzy Membership Function for Age Comparison with Crisp Data Sets.....	94
Figure 5-17: Fuzzy Membership Function Arbitrary Configuration Table	96
Figure 5-18: Process of Calculating Contribution Weightages for Subjective Fuzzy Membership Function	96
Figure 5-19: Hybrid Fuzzy Membership Function	97
Figure 5-20: $h(x)$ $g(x)$ Fuzzy Membership Function Derived from $f(x)$ and $g(x)$	98
Figure 5-21: $f(x)$ and $g(x)$ Fuzzy Membership Functions.....	99
Figure 5-22: Acreage Fuzzy Membership Function	101
Figure 5-23: Trees Membership Function	102

Figure 5-24: Derived Fuzzy Membership Function for Value of Plantation Field	104
Figure 5-25: Five State Fuzzy Membership Function for Experience	110
Figure 5-26: Three State Fuzzy Membership Function for Experience.....	111
Figure 5-27: Fuzzy Membership Function Linguistic Configuration Table	112
Figure 5-28: Different Linguistic Variables for Employees Experience	114
Figure 5-29: Integration of Multiple Fuzzy Membership Functions.....	115
Figure 6-1: Standard Warehouse Design for a Plantation Attendance System.....	119
Figure 6-2: DimRange Dimension.....	121
Figure 6-3: Fuzzy Range Dimension Configuration.....	123
Figure 6-4: Fuzzy Membership Function for Age	124
Figure 6-5: Employee Experience in Fuzzy Presentation	126
Figure 6-6: Implementation of Type 1 SCD	129
Figure 6-7: Implementation of Type 2 SCD	130
Figure 6-8: Implementation of Type 2 SCD for Fuzzy Configuration Tables.....	131
Figure 6-9: Implementation of Type 2 SCD for Fuzzy Contribution Table	132
Figure 6-10: OLTP Design of Product and Related Tables	134
Figure 6-11: De-normalized DimProduct Table	135
Figure 6-12: Start Schema Which Includes DimProducts	136
Figure 6-13: Hierarchical Analysis for Data Warehouse using Pivot Table.....	137
Figure 6-14: Separation of Category Table in Dimensional Modeling to Support Fuzzy Categorization	138
Figure 6-15: Separation of Category Table in Dimensional Modeling to Support Fuzzy Categorization	139
Figure 6-16: Inter Valued Fuzzy Sets for Categorization for Normal Horizontal Method.....	143
Figure 6-17: Comparison of Normal and Ranked Horizontal Method for Fuzzy Membership Function	145
Figure 6-18: Inter Valued Fuzzy Sets for Categorization for Ranked Based Horizontal Method	146
Figure 6-19: Comparison of Normal Horizontal, Ranked Horizontal Method and Pairwise Comparison for Fuzzy Membership Function.....	147

Figure 6-20: Comparison of the Standard Deviations for Normal Horizontal, Ranked Horizontal Method and Pairwise Comparison for Fuzzy Membership Function.....	150
Figure 7-1: Table Schema of Fuzzy Contribution.....	153
Figure 7-2: Separation of Category Table in Dimensional Modeling to Support Fuzzy Categorization	154
Figure 7-3: Physical Separation of Survey Data and Fuzzy Data Warehouse	155
Figure 8-1: Star-Schema for fctDailyWork	159
Figure 8-2: Implementation of Classical OLAP Cubes using SQL Server Analysis Service 2016....	160
Figure 8-3: Physical Separations of Cubes depending on Fuzzy Dimension	162
Figure 8-4: Star Schema Fuzzy OLAP Cube for Fuzzy Attributes Number of Trees for Single Measure	164
Figure 8-5: Star Schema Fuzzy OLAP Cube for Fuzzy Attributes Number of Trees for Multiple Measures	165
Figure 8-6: Slicing Operations for Fuzzy Cube – Example 1	167
Figure 8-7: Slicing Operations for Fuzzy Cube – Example 2.....	168
Figure 8-8: Dicing Operations for Fuzzy Cube	169
Figure 9-1: Configuration Tables for Membership Function in Fuzzy Data Warehouse	174
Figure 9-2: Schema Definition of Fuzzy Contribution Table	178
Figure A-1: Table Structures for Transaction Fact Table	194
Figure A-2: Table Structures for Snapshot Fact Table	195
Figure A-3: Evolution of an Accumulating Snapshot Fact Row	195
Figure A-4: Table Structures for Accumulating Snapshot Fact Table.....	196
Figure A-5: Table Structures for Fact-Less Fact Table	198
Figure B-6: Dimension Type 1	200
Figure B-7: Dimension Type 2	200
Figure B-8: Dimension Type 3	201
Figure B-9: Mini-Dimension and Type 1 Outtrigger.....	201
Figure B-10: Add Type 1 Attribute to Type 2 Dimension.....	202
Figure B-11: Dual Type 1 and Type 2 Dimension.....	202

Figure C-12: Date Dimension Proposed by Ralph Kimball..... 205

Figure D-13: Triangular Function..... 206

Figure D-14: S Function 207

Figure D-15: Trapezoidal Function..... 208

Figure D-16: Gaussian Function..... 209

Figure D-17: Exponential Like Function..... 210

Figure D-18: Exponential Like Function..... 211

Figure G-19: Properties of Fuzzy Membership Function 215

Figure H-20: Typical Membership Functions of the term set T (age) : Source: Mathworks..... 216

Figure H-21: Primary Linguistic Values and Composite Linguistic Value 218

Figure J-22: Most Popular Database Systems in 2018 August 220

Figure J-23: Most Popular Software Programming Languages in 2015 Source: www.ieee.org 220

Figure J-24: KDnuggets Analytics, Data Science, Machine Learning Poll 2015-2017..... 221

Figure K-25: Spider Diagram of Fuzzy Data Warehouse Research 222

Figure M-26: Boehm’s NFR List..... 228

Figure M-27: McCall’s NFR List 229

Figure Z-28: Example for Star Schema 256

Figure Z-29: Example for Snowflex Schema 257

LIST OF TABLES

Table 2-1: Comparison of Properties for MOLAP and ROLAP	41
Table 3-1: Sub Tasks for Research Objectives	53
Table 4-1: Range Dimension for Age and Income	66
Table 5-1: Mean, Standard Deviation and Standard Error of the Mean of the Box Plots.....	82
Table 5-2: Ranges of Employee Age Range Dimension	86
Table 5-3: Subset of Data Sample Weightages for Employee Age	88
Table 5-4: Subset of Data Violation of Height of Membership Function for Age	88
Table 5-5: Different Fuzzy Membership Function Parameters.....	95
Table 5-6: Rules for Derived Attributes	99
Table 5-7: Combination of Acreage and Number of Trees.....	100
Table 5-8: Membership Function for Acreage in Formula	101
Table 5-9: Membership Function for Trees in Formula.....	103
Table 5-10: Sample Data Set of Filed.....	103
Table 5-11: Sample Data Membership Function for Trees in Formula	104
Table 5-12: Comparison of Importance State Between Fuzzy and Rules Techniques	105
Table 5-13: Confusion Matrix for Importance Attribute of Plantation Field.....	105
Table 5-14: Five State and Three Fuzzy Membership Function Parameters for Employee Experience	108
Table 5-15: Sample Linguistic Variable Configuration.....	113
Table 6-1: Sample Data for Range Dimension	120
Table 6-2: Fuzzy Membership Function Configuration Table Data.....	123
Table 6-3: Fuzzy Contribution Table Sample Data	124
Table 6-4: Primary Fuzzy Contributions with the Comparison of Crisp State	126
Table 6-5: Primary Fuzzy Contributions for Employee Experience.....	127
Table 6-6: Confusion Matrix for Fuzzy Range for Experience	128
Table 6-7: Confusion Matrix for Fuzzy Range for Age.....	128
Table 6-8: Comparison of Corrections rates of Experience and Age	129

Table 6-9: Sample Data Set for Fuzzy Contribution.....	132
Table 6-10: Weightages of Dimension and Category	138
Table 6-11: Survey Results for Coconut Oil for Different Categories	141
Table 6-12: Standard Deviation and Range of Inter-Valued Fuzzy Set.....	143
Table 6-13: Survey Results for Coconut Oil for Different Categories with Ranking Weightages	144
Table 6-14: Survey Results for Coconut Oil for Different Categories with Pairwise Comparison	146
Table 6-15: Comparison of Actual and Normal Horizontal Method	148
Table 6-16: Comparison of Actual and Ranked Based Method.....	149
Table 6-17: Comparison of Actual and Pairwise Comparison Method	149
Table 8-1: Query Output for Named Query in Fuzzy OLAP Cube	161
Table 8-2: Query Output for Named Query in Fuzzy OLAP Cube for One OLAP Cube and Single Measure.....	163
Table 8-3: Query Output for Named Query in Fuzzy OLAP Cube for One OLAP Cube and Multiple Measures	164
Table 9-1: Subset of Data Violation of Height of Membership Function for Age	173
Table 9-2: Configuration Tables	174
Table 9-3: Configuration of Membership Function Configuration.....	175
Table 9-4: Configuration of Fuzzy Membership Function Arbitrary Configuration	175
Table 9-5: Configuration of Fuzzy Membership Function Linguistic Configuration.....	176
Table 9-6: Configuration of Derived Membership Function Configuration.....	176
Table 9-7: Configuration of Fuzzy Contribution	178
Table A-1: Different Types of Fact Tables	196
Table B-2: Different Types of Dimensions.....	199
Table C-3: Different Types of Fact Tables	204
Table E-4: Different Fuzzy Operations.....	212
Table S-5: Different Durations to Generate Fuzzy Contribution	243
Table S-6: Different Durations to Standard and Fuzzy OLAP Cubes	243
Table V-7: Membership Contribution for Selected Field Hectare	246

Table V-8: Membership Contribution for Selected Field Trees	246
Table V-9: Combination of Membership Functions of Trees and Hectare.....	246
Table V-10: Rules for Importance	246
Table V-11: Multiplication of Contribution.....	247
Table V-12: Aggregation of Contribution for Importance.....	247
Table W-13: Output for Traditional Categorization of Data Warehouse.....	248
Table W-14: Output for Fuzzy Categorization of Data Warehouse.....	249
Table Z-15: Different Types of Fact Tables	255

Abbreviations

OLAP	Online Analytical Processing	NFR	Non-Functional Requirements
OLTP	Online Transactional Processing	ANN	Artificial Neural Network
ETL	Extract-Transform-Load	HMF	Horizontal Membership Function
BI	Business Intelligence	MF	Membership Function
MIS	Management of Information Systems	DBMS	Database Management System
CRM	Customer Relationship Management	SCD	Slowly Changing Dimension
HR	Human Resource	CDC	Change Data Capture
ERP	Enterprise Resource Planning	MDX	Multidimensional Expressions
KPI	Key Performance Indicators	MOLAP	Multidimensional Online Analytical Processing
FK	Foreign Key	ROLAP	Relational Online Analytical Processing
PK	Primary Key	HOLAP	Hybrid Online Analytical Processing

SVM	Support Vector Machine	MDDDB	Multi-Dimensional Database
FD	Fuzzy Dimension	FC	Fuzzy Cube
AI	Artificial Intelligence	BI	Business Intelligence
ML	Machine Learning	RFI	Recency – Frequency - Intensity
RFM	Recency – Frequency - Monetary	SSIS	SQL Server Integration Services
SSAS	SQL Server Analysis Service	FIS	Fuzzy Inference System
DOM	Degree of Membership	IQR	Inter-Quartile Range
FIS	Fuzzy Inference System		