Stony Brook University

A Medical Decision Model for Tinnitus Treatment Assessment

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Hong Don Ihn

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Abstract

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Tinnitus means objective somatosounds, and subjective auditory or sensorineural perception of noise without external physical sounds. There are several tinnitus treatments, but it is difficult to ascertain how otorhinolaryngologists rank the alternatives of treatments due to the insufficiency of available evidence and standards. A hierarchical decision model (HDM), a popular multi-criteria decision analysis (MCDA) method, can help to implement a comprehensive assessment of tinnitus treatments and rational decision-making to select the appropriate tinnitus treatments. The HDM considers a holistic approach using multiple dimensions, criteria and expert judgments to acquire the relative ranking of candidate tinnitus treatments. The four dimensions selected by experts for the study of tinnitus are diagnostic categories, clinical evaluation, duration and efficiency (DCDE). The purpose of this dissertation research is to perform a case study using the initial and intermediate HDM frameworks for comprehensive tinnitus treatment assessment (TTA)

with qualified decision makers: Korea's otorhinolaryngologists with a specialty in tinnitus. The verified HDM (v-HDM) consists of the DCDE dimensions and their associated criteria. A research instrument is designed to obtain expert judgments from the otorhinolaryngologists. The expert judgments are then used to rank the dimensions, criteria and alternatives of candidate tinnitus treatments in the HDM. The alternatives are also assessed directly with respect to the mission, the four dimensions and the twelve criteria. The results of expert judgment quantification are indicated by treatment values, which range from 0 to 100. The HDM is employed for an interdisciplinary medical decision model to establish DCDE multidimensional standards for tinnitus treatment assessment (TTA).

Keywords: medical decision model, multidimensional assessment, decision model, expert opinion/judgment, expert judgment quantification, medical treatment management, counseling, sound therapy, music therapy, surgery, tinnitus, pharmacotherapy, tinnitus treatment assessment (TTA), tinnitus management (TM), hierarchical decision model (HDM), multi-criteria decision analysis (MCDA), health education research, health Information Technology (IT), health informatics, health innovation & care, health policy.

Dedication Page

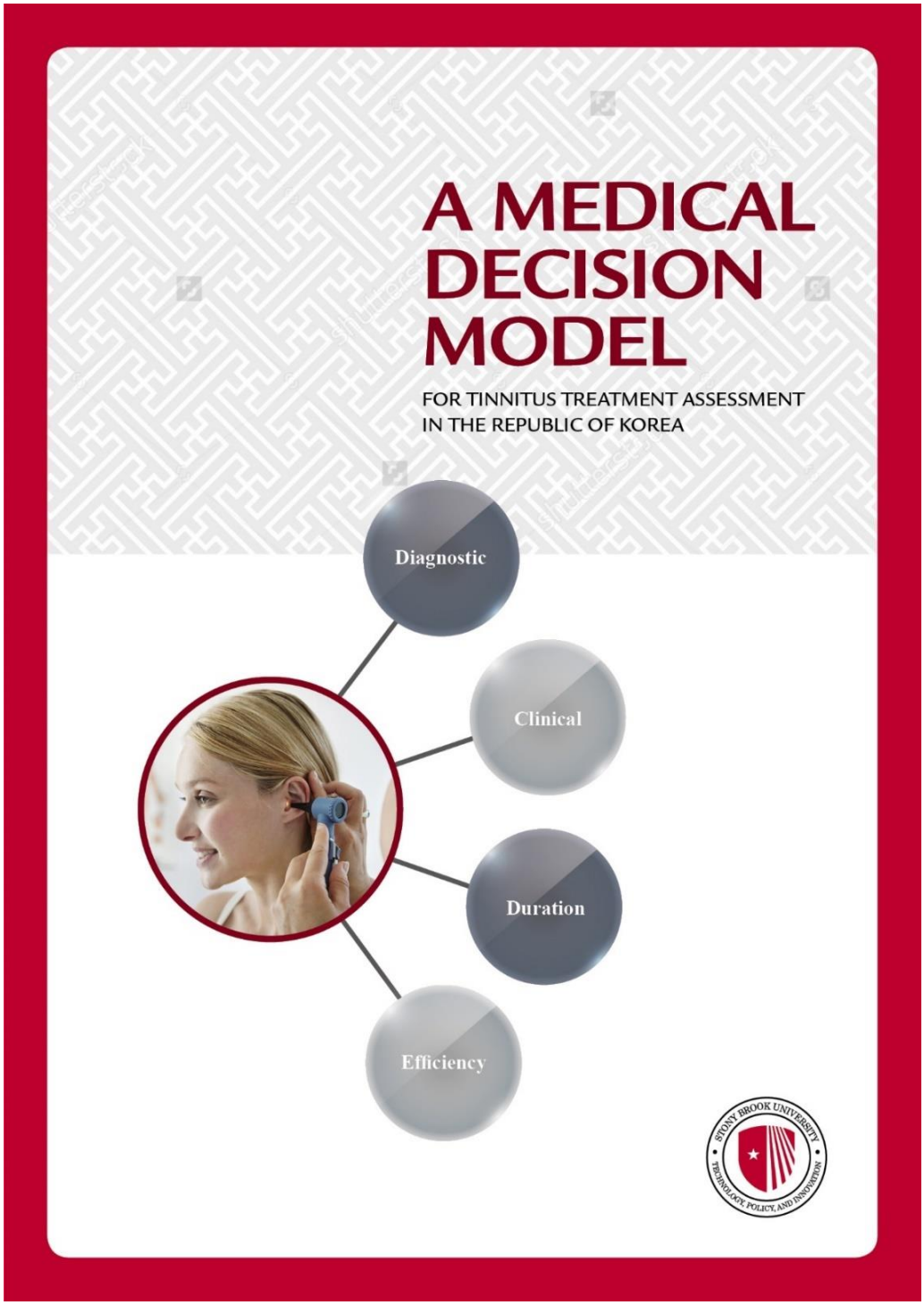
To my Lord Jesus Christ and my family.

Thank you for your steadfast love and overflowing hope forever.

1. *Korea's family: Dearest Hye Yun (Angelina) Park, Tae Hyeon (Daniel) Ihn, Yong Sik Kim, Min Ok Yook, Byung Chil Park and Eun Suk Lee*

2. *The academic family: Joyce Flynn, Kyung Hoon Kim, David L. Ferguson, Nasir J. Sheikh, Jung Eun (Grace) Shin, Enu Jin Son, Ji Jung Im, Eui Cheol Nam, Shi Nae Park, Young Jin Kim, Jong Yang Kim, Hyun Joon Shim, Jae Jin Song, In Seok Moon, Jong Dae Lee, Myeong Hyeon Song, Yong Keun Yoo, Young Shin (Aaron) Kim, Tae Jin Kim, Chan Sok (Francis) Kim, Elizabeth Baron, Sara Santos, Debra Dwyer, Thomas Woodson and Choon Ho (Joshua) Kim.*

Frontispiece



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List of Abbreviations

CBT: Cognitive Behavioral Therapy

CI: Cochlear Implantation

DCDE: Diagnostic categories, Clinical evaluation, Duration and Efficiency

HDM: Hierarchical Decision Model

LOD: Level of Disagreement

LOI: Level of Inconsistency

MCDA: Multi-Criteria Decision Analysis

MDCA: Mission, Dimension, Criterion and Alternative

OTR: Occupational Therapist

PCM: Pair-wise Comparison Matrix

QOL: Quality of Life

SNHL: Sensorineural Hearing Loss

TFI: Tinnitus Functional Index

THI: Tinnitus Handicap Inventory

TM: Tinnitus Management

TRQ: Tinnitus Reaction Questionnaire

TV: Treatment Value

TTA: Tinnitus Treatment Assessment

TRT: Tinnitus Retraining Therapy

VAS: Visual Analogue Scale

VR: Virtual Reality

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Chapter 1

Introduction

1.1 Background

Tinnitus is a bothersome disorder described as a ringing sound within the human ear that occurs without a trigger from external auditory sounds. Tinnitus may be classified as a common audiological and neuronal disorder that occurs within the general population. Treatments for tinnitus have been a problem addressed at length by otorhinolaryngologists and audiologists (Belli et al., 2008). Affected individuals with tinnitus tend to accept the disorder with some degree of treatment, but tinnitus reduces their quality of life (QOL) and has been associated with hearing loss. Severe tinnitus causes considerable distress among a significant population who then demands to visit hospitals frequently for tinnitus treatment (Hesser, Weise, Westin, & Andersson, 2011).

In the UK, tinnitus affects 10% to 15% of the population. Exposure to noise and degenerative diseases are apparently related to tinnitus. Tinnitus is at the root of issues that affect quality of life, including insomnia, hearing disorders, communication disabilities, difficulties in concentration and emotional disturbances related to depression and irritability (Hoare, Kowalkowski, Kang, & Hall, 2011). 57% of tinnitus patients suffer from sleep disturbances, and one percent of tinnitus affliction is disabling to patients (Baracca et al., 2007). Approximately 3% to 5% of adult patients

with tinnitus are severely distressed and confront manifest handicaps in their everyday life in work, social activities and sleep. Severe tinnitus, without appropriate treatment, may be conducive to hazardous social costs (Hesser et al., 2011).

Multiple treatment methodologies have been suggested for tinnitus treatment guidance, but the guideline is limited because it does not account for multiple dimensions. Therefore, it cannot be implemented in an all-inclusive tinnitus treatment assessment. First, the multifarious tinnitus treatments could be an obstruction to its management. Secondly, even though there are beneficial tinnitus treatments to some extent for the majority of patients, a substantial percentage of tinnitus patients is indoctrinated to accept tinnitus (Elgoyhen & Langguth, 2011). Furthermore, current tinnitus treatments of sound therapy with hearing aids, pharmacotherapy, counseling and other medicine have been found to be lacking to offer complete relief of this sensorineural disorder (Hesser et al., 2011).

A hierarchical decision model (HDM) with expert judgments can be used to address the relative rankings of tinnitus treatments. The HDM consists of a hierarchical structure and the levels of its decision elements include: the mission which is the overall objective, the four DCDE dimensions (or D1, D2, D3, and D4), and the criteria associated with each dimension. An HDM criterion may consist of sub-criteria or factors. The bottom level of the HDM includes the tinnitus treatment alternatives under consideration. The decision elements at different appropriate levels are ranked with respect to: (1) the top level: the mission, (2) the second level: dimensions and (3) the third

level: criteria. The rankings are obtained by expert judgments using ratio-scale pair-wise comparisons (RSPC). These comparisons are converted to relative fractional ranking values that range from 0 to 1, which total a constant sum of 1.00 for that level. For example, the ranking values of four dimensions with respect to the mission may turn out to be D1: 0.24, D2: 0.42, D3: 0.17 and D4: 0.17, which total 1.00, as illustrated in Figure 1.

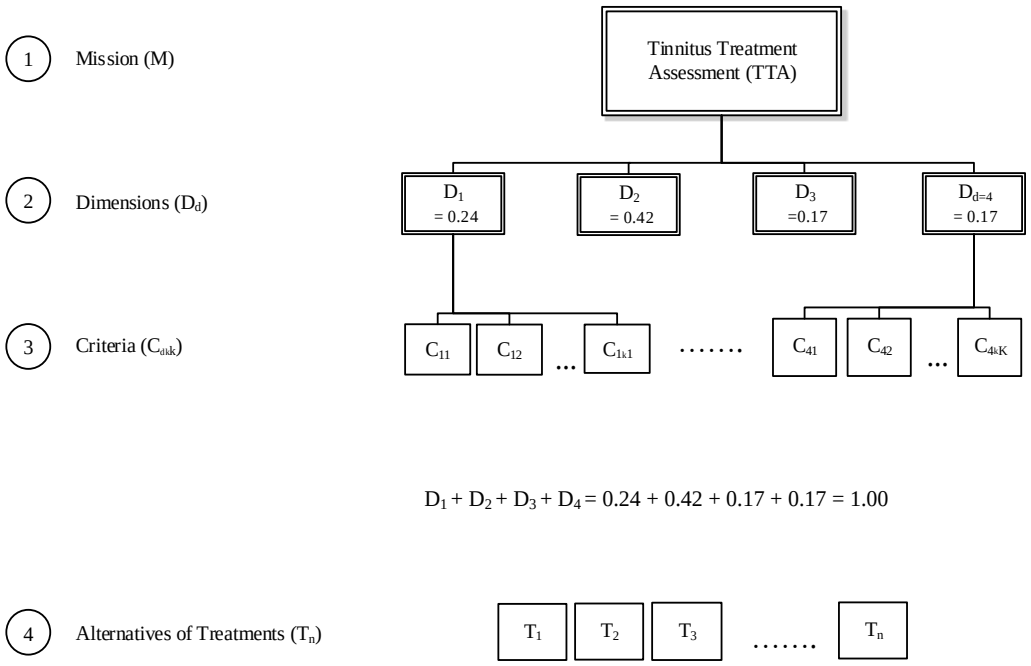


Figure 1: Example of an HDM with Multi-level Assessment of Tinnitus Treatments with Respect to the Mission, Dimensions, and Criteria

The multi-criteria decision analysis (MCDA) using the dimensions of diagnostic categories, clinical evaluation, duration and efficiency (DCDE) can be applied to set appropriate standards that will allow otorhinolaryngologists to evaluate different types of tinnitus treatments. Clinicians have sought “evidence-based” guidelines for a strategic tinnitus management (TM) (Yoo et al.,

2013). An HDM requires the collaboration between MCDA researchers and physicians, who are decision makers, to achieve a mission of comprehensive tinnitus treatment assessment (TTA). A case study of this HDM demonstrates a multidimensional TTA to decide the appropriate tinnitus treatment among the alternatives of treatment based on the judgments of Korea's experts.

1.2 Multiple Dimensions

Tinnitus can be a complex condition related to auditory disorders and illnesses with divergent causes (Elgoyhen & Langguth, 2011). Dundar F. Kocaoglu introduced a systematic process of complex evaluations using multidimensional levels of a network of hierarchical decision relationships (Kocaoglu, 1983). A comprehensive systematic approach to a decision-making model of tinnitus treatment considers multiple dimensions that reflect the disparate perspectives of clinicians and compound criteria. This systematic approach uses expert judgments and assesses alternative categories of treatment. The analytical framework has fundamental elements: the mission to achieve, information to lay out the options, demonstration of decision for each alternative, comparative measurements with regard to each criterion and conclusive analysis of decisions (Stokey, 1978). The identification of multiple dimensions is a descriptive framework for each expert. The tinnitus dimensions refer to a diagnostic category, clinical evaluation, duration and treatment efficiency. The research instrument, which consists of 90 pair-wise comparison questions that will be answered by otorhinolaryngologists as members of an expert judgment panel, will validate the decision model and then rank the dimensions and their associated criteria. A systematic approach to the experts' decision is required to contemplate a more comprehensive evaluation of treatments to find a cure for complex disorders including tinnitus.

The goal of this research is to compile a comprehensive tinnitus treatment assessment (TTA) using a hierarchical decision model (HDM). The HDM is the main research methodology that applies multiple dimensions for attributing multi-level evaluations to a comprehensive TTA. While establishing an HDM framework, a literature review of specific and specialized studies of tinnitus treatments assists in ascertaining the available multiple levels of dimensions and associated criteria for TTA. For instance, the diagnostic dimension integrates two types of criteria of objective and subjective tinnitus. A durational dimension includes two criteria of acute and chronic tinnitus.

To consider the clinicians' perspectives on a range of decisions for tinnitus treatments, an expert panel provides feedback that compiles multiple dimensions and criteria that are currently being discussed among professionals. In multi-criteria decision analysis (MCDA), each criterion institutes the first level dimension, and each distinguishable sub-criterion is a decision factor that constitutes the second level criterion related to each dimension. We iterate and reiterate reviews of experts' opinions to reach a consensus of the four TTA multiple dimensions, which are diagnostic categories, clinical evaluation, duration, and efficiency (DCDE). Chapter 6 defines the four DCDE dimensions and the associated criteria in detail.

The literature review related to dimensions and criteria reveals limitations of the research scope and competence to manipulate a heterogeneous collection of criteria for an all-inclusive tinnitus

treatment assessment. Multi-DCDE dimensions and visible criteria refer to the coordinated attributes for decision modeling that initiate the TTA.

1.3 Research Scope

The purpose of this research is to contextualize why tinnitus treatments confront a wide range of problems and how otorhinolaryngologists assess tinnitus treatments with novel and holistic approaches using the following decision elements: mission (M), multiple dimensions (D), associated criteria (C) and alternatives (A) in the hierarchical decision model (HDM). The HDM framework addresses the following contexts: (1) the literature for the proposition of decision elements of mission, dimension, criterion and alternative (MDCA), (2) the experts for feedback and judgments with respect to the MDCA decision elements, (3) the research instrument for the multidimensional assessment, and (4) the policy implications of treatment values (TVs) for otorhinolaryngologists, who are the main decision makers in the HDM. The decision elements — dimensions and their criteria — allow us to evaluate the treatment alternatives using a relative ranking. The results of the ranking values affect the policy decisions for the clinicians to motivate new multidimensional tinnitus treatment assessment. In sum, the HDM denotes a comprehensive decision approach with multiple dimensions and their associated criteria. The disparate dimensions are applied in the HDM to consider the decision makers' perspectives.

This new comprehensive decision approach helps to decide the appropriate tinnitus treatments in multifaceted milieus with competing and contrasting dimensions and criteria. The contemplation of an all-inclusive tinnitus treatment assessment may influence collaboration among physicians,

occupational therapists (OTR), and interdisciplinary researchers to increase effectiveness, safety and compliance. Future studies can utilize the improved tinnitus diagnostics and the innovative clinical evaluation technologies in the mission to develop a multidimensional tinnitus treatment assessment.

The gap analysis results of the literature review propose the following research questions:

(1) What are the attributes of designing a treatment assessment model with multiple dimensions and their associated criteria?

(2) What is the feasible position of this decision model to evaluate tinnitus treatments with physicians and multidisciplinary researchers?

(3) How can otorhinolaryngologists use this multidimensional tinnitus treatment assessment for their reinforced decision-making process and to establish a more confident clinical standard?

However, the expert panel of otorhinolaryngologists and the designer of the research instrument have compromised on the number of dimensions and criteria for a feasible decision-making model. For instance, the four coordinated DCDE dimensions reveal the scope and limitation of this research, which allows us to initiate a new study of multi-dimensional assessment of tinnitus treatments.

Chapter 2

Literature Review

2.1 Introduction

In the US, up to 16% of the total population (Bertet et al., 2013), exceeding 50 million citizens (Tunkel et al., 2014a), have suffered from tinnitus-related symptoms. Within the total population, 10% to 15% are predicted to be adults. This is only, however, an estimate because the prevalence studies are not standardized. In particular, the age group between 60 and 79 has a higher prevalence for tinnitus (Henry et al., 2005). In Europe, people in Norway participated in large-scale surveys, and tinnitus was perceived in 21.3% of males and 16.2% of females, while 4.4% of the men and 2.1% of the women were diagnosed with severe tinnitus (Langguth, Kreuzer, Kleinjung, & Ridder, 2013). In the Republic of Korea (ROK), 21.4% of the population aged 20 to 97 — 19.5% of males and 22.8% of females — experienced regular tinnitus symptoms. 7.3% of the adults — 6.8% of men and 7.7% of women — struggle with severe tinnitus (R.J. & J.D., 2014). Other national survey data for tinnitus epidemiological studies present almost quasi-values of prevalence in other countries in Asia, Europe, and Africa (Langguth et al., 2013). Global trends associate tinnitus with hearing disorders and degenerative diseases. Overall, population growth and the increasing exposure to environmental and personal noise with mobile devices are potential risk factors contributing to tinnitus (Langguth et al., 2013).

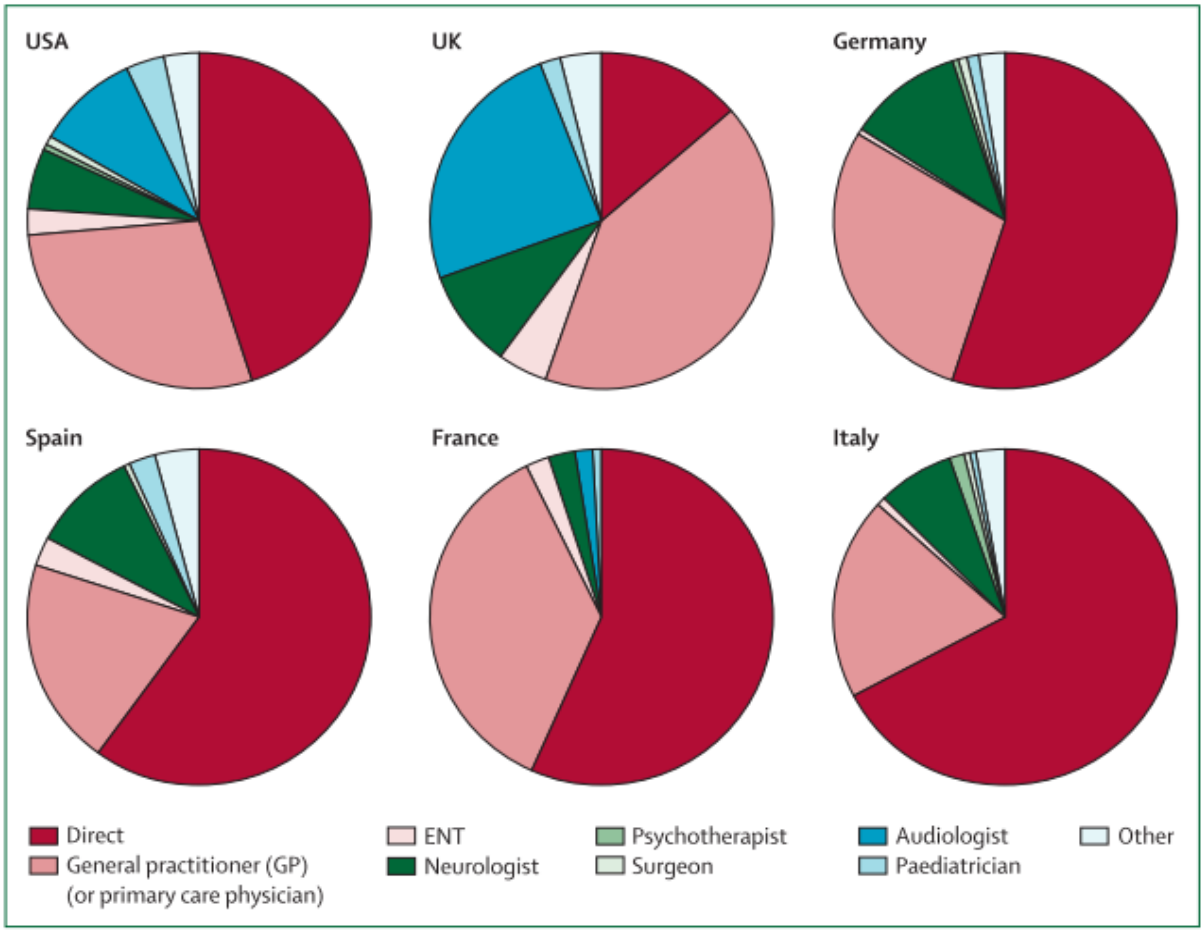


Figure 2: Contact Channels to Make a Referral to Otorhinolaryngologists for Tinnitus Treatment (Baguley, McFerran, & Hall, 2013)

Although the contact channels to reach otorhinolaryngologists for the cure of tinnitus are intensively divergent among countries (Figure 2), the exclusive proportion consists of general practitioner and otorhinolaryngologist, who are in charge of the main activities in overall contact channels. In particular, the role of audiologists is relatively important in the USA and the UK because of their professional position for audiological evaluation and sound therapy (Baguley et al., 2013). Thus, the collaborative system between audiologists and otorhinolaryngologists may be applicable in the UK and USA. Pediatricians can assist in the care of childhood tinnitus, and

psychotherapists aid adult patients with a psychological evaluation to assist in the treatment of severe tinnitus, as detailed in Section 1.1.

For sufficient tinnitus relief, the recent tinnitus management (TM) is probably limited in its ability to achieve an evidence-based assessment of tinnitus treatments. To improve TM, there are novel tinnitus pathophysiological models to examine the complex sensorineural pathways after cochlear lesions. Furthermore, virtual reality (VR) technologies have been suggested to take more comprehensive measures in chronic tinnitus features (Bertet et al., 2013). The collaborative TM with innovative clinical models and technologies may promote adequate medical care for tinnitus.

Initiatives for advanced tinnitus treatments have been discussed with multiple medical specialties and complementary sciences, including otorhinolaryngology, neuroscience, psychiatry, geriatrics, audiology, nanotechnologies, brain science, biological science, psychological science and behavioral science. Specialists, who are in neuropsychology, neuropathology, neurobiology and behavior science, have also been interested in a multidisciplinary diagnosis of tinnitus.

The literature review of tinnitus clinical studies aims at a concise overview for consilience with respect to multiple dimensions and multilevel criteria of tinnitus treatments. This review may be informative for the decision makers, otorhinolaryngologists, because this literature outlines tinnitus treatment options and assesses alternative treatments.

The literature review is an indispensable part in describing research background, motivation, novel approaches of a multidimensional framework and the research methodology of the hierarchical decision model (HDM) for an integrative tinnitus treatment assessment (TTA). For instance, multilateral national studies address the substantial prevalence of tinnitus with global demographics. The reports of clinical tinnitus present social risk factors associated with tinnitus-related disorders that linger with reduced global patient quality of life (QOL) (Bertet et al., 2013; Tunkel et al., 2014a). The gaps in the literature present the value of multiple dimensions and multilevel criteria for comprehensive TTA, because tinnitus is a complex sensation or a sensorineural disorder with multifaceted pathological and etiological causes, as well as comorbid chronic diseases (Elgoyhen & Langguth, 2011).

2.2 Review Categories

This literature review is required to explore three categories: tinnitus treatments, multiple dimensions and references for a hierarchical decision model (HDM). To access the major international journals and their published papers, this multidimensional tinnitus treatment assessment study uses 665 databases from the Stony Brook Library, including *PubMed* and Korea's medical databases such as *KISEP* and *KoreaMed*, as well as *Google Scholar*. In particular, the expert panel recommended credible authors and papers about tinnitus and TTA. The specialized tinnitus clinical approaches are essential to validate and examine the research papers in the first category of tinnitus treatments. The second category of the literature of multiple dimensions is useful to initiate the conceptual framework to design a decision model to assess the alternatives of tinnitus treatments. In the last category of the hierarchical decision model (HDM),

the mission or objectives to determine the multidisciplinary perspectives reveals the multidimensional attributes and the multilevel assessment of the alternatives (Linkov et al., 2006). Furthermore, gaps in the multi-criteria decision analysis (MCDA) encourage the critical review of the research methodology using the HDM. Case studies of the HDM provide the practical guidelines for the conceptual framework of a decision model. Figure 3 illustrates the main concept of the three categories that radiate from the multi-dimensional assessment of tinnitus treatments. The activities of categories 1, 2 and 3 are explained as follows:

- Category 1: Investigating multifaceted tinnitus treatments to develop alternatives in the decision-making model.
- Category 2: Observing the multiple dimensions for a comprehensive assessment of tinnitus treatments.
- Category 3: Reviewing research methodologies and their applications based on a hierarchical decision model (HDM).

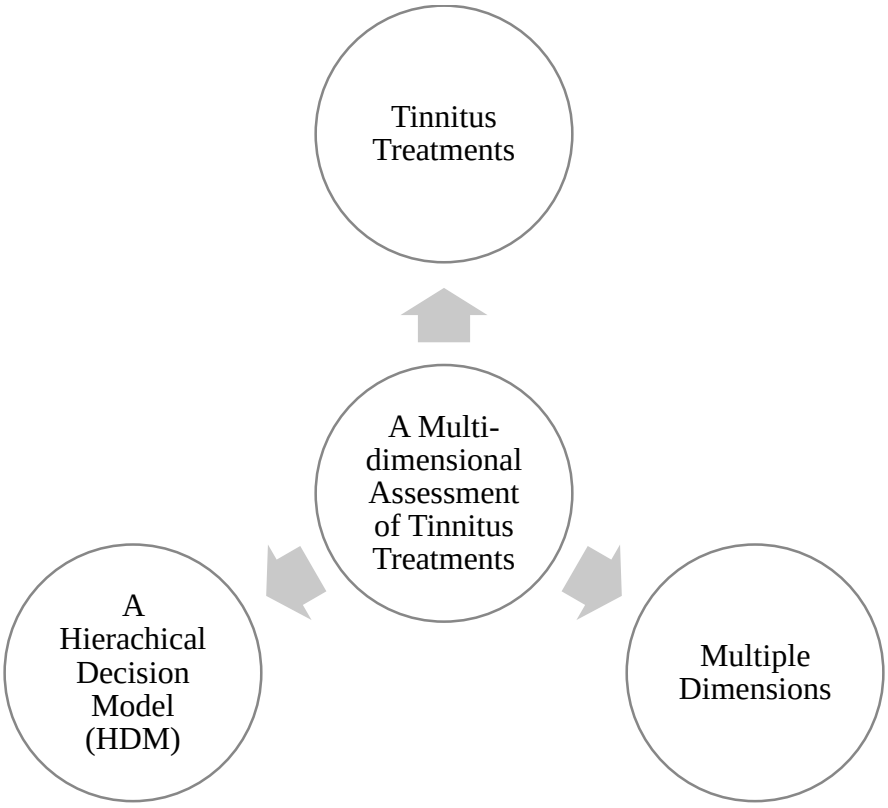


Figure 3: Categories of Literature Review for a Multidimensional Tinnitus Treatment Assessment (TTA)

2.3 Tinnitus Treatments

Tinnitus is a prevalent and complex sensation, which is most of the time chronic and degenerative, but there is no definite treatment for it (Cima et al., 2009; Han, Lee, Oh, Chang, & Suh, 2015; Hesser et al., 2011; Langguth et al., 2013; Scherer et al., 2014; Tunkel et al., 2014a, 2014b). This common medical disorder is a debilitating disease with a decreased quality of life (QOL) and several risk factors: hearing loss, otological disorders, ototoxic medication, head injury, anxiety and depression (Baguley et al., 2013).

There is no standardized evaluation for a tinnitus demographic study, and Korea's national tinnitus survey used the reformed tinnitus questionnaire from the United States National Health and Nutrition Examination Survey (Park & Moon, 2014). Furthermore, adults aged over 65 years old present a prevalence of tinnitus of 31.5% (Park & Moon, 2014), and children also suffer from bothersome tinnitus-related disorders, such as hearing loss and severe anxiety (Bae et al., 2014). In current studies, the occurrence of tinnitus in children and adolescents is escalating with the increasing risk factors of noise exposure from everyday wearable devices, such as audible toys, tablet PCs, smartphones and MP3 players (Bae et al., 2014).

No sufficient evidence-based effective pharmacotherapy or medicine for tinnitus is assured despite substantial research efforts to develop tinnitus treatments. Otorhinolaryngologists may suggest surgery for pathological tinnitus, but post-surgery tinnitus can linger on. The other options for tinnitus treatments may be counseling and sound therapy with hearing aids or sound generators, which includes music therapy and wide-band sound therapy. Counseling-based tinnitus treatments are cognitive behavioral therapy (CBT) and tinnitus retraining therapy (TRT). TRT or sound therapy with CBT are effective to some extent, though with reduced availability. Thus, the clinical practices for the treatment of assorted tinnitus patients reveal insufficient evidence-based tinnitus treatment (Baguley et al., 2013).

A decision model is needed to address the complexity of tinnitus treatment. In particular, the hierarchical decision model (HDM) is considered in Chapter 4 to identify research questions and

tinnitus treatment assessment (TTA) with multiple dimensions and the associated criteria. In a gap analysis of the literature of tinnitus treatments, multi-dimensional attributes and multi-criteria are classified by the comprehensive TTA approaches.

2.4 Review Process

The mission of this study is the comprehensive tinnitus treatment assessment (TTA) using multiple dimensions. The mission, which is the top level of a hierarchical decision model (HDM), depicts the umbrella of the HDM. The five-step process of the literature review consists of Step 1: the review of the status of tinnitus and the current TTA; Step 2: the review of the dimensions; Step 3: the review of the criteria; and Step 4: the review of the sub-criteria or factors. In Step 5 — the review of the HDM — the preceding steps are requisites for the evaluation of tinnitus treatment alternatives in the literature review, as illustrated in Figure 4.

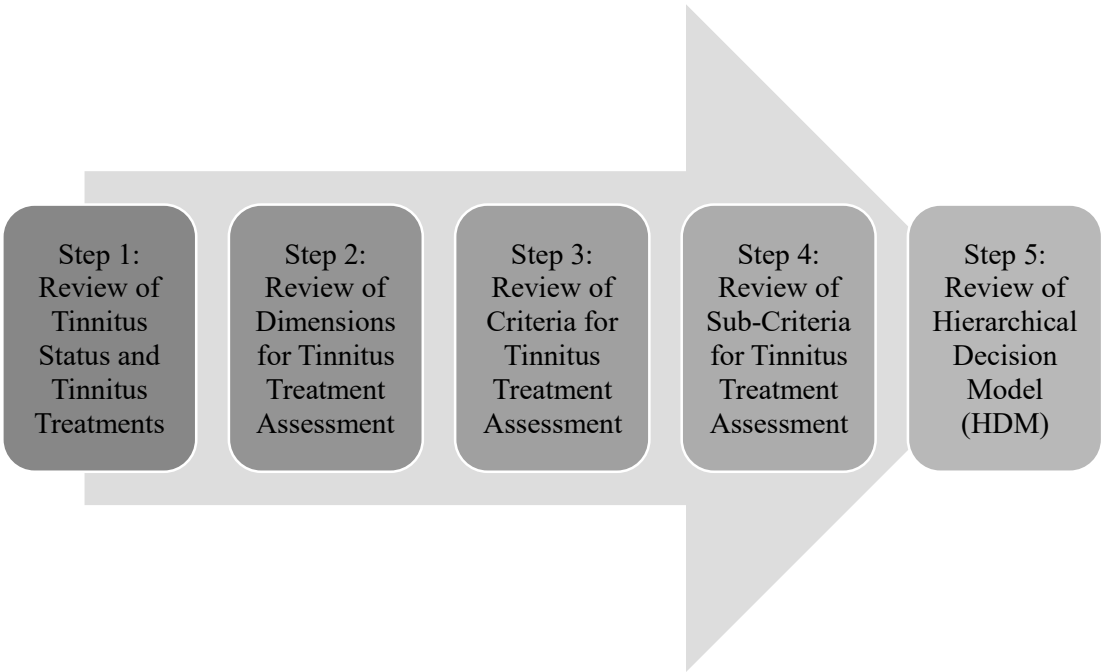


Figure 4: Five-Step Process of the Literature Review

The literature review process is designed to build the body of knowledge for the research objective: the multidimensional assessment of tinnitus treatments using an HDM. In Step 1, the first literature review presents the definition of tinnitus and its current status: the prevalence of tinnitus and available tinnitus treatments. In Steps 2, 3 and 4, the decision elements — multiple dimensions, multifaceted criteria and appropriate tinnitus treatment alternatives — are addressed based on the gap analysis of the literature review.

The primary domain of this research is treatment assessment (TA). The secondary field includes the specialties of otorhinolaryngology for tinnitus treatment with the multi-dimensional TA based on expert judgments. For the management of the libraries of researched literature and the gap analysis, the literature review tool has been operationalized by a Mendeley Desktop (MD) software. The literature libraries were classified and managed by using this MD program. Table 1 provides the main list of available databases for the literature review. The searching keywords were tinnitus, tinnitus treatment, counseling, pharmacotherapy, sound therapy, surgery, tinnitus treatment assessment, hierarchical decision model (HDM) and multi-criteria decision analysis (MCDA). In total, 72 publications are available in the three categories of the literature review, as shown in Table 2.

Table 1: List of Available Databases of Researched Literature

Available Databases
PubMed: The United States National Library of Medicine (NLM) at the National Institutes of Health (NIH)
KoreaMed
Web of Science Direct
CINAHL: Cumulative Index to Nursing and Allied Health Literature
MEDLINE: Medical Literature Analysis and Retrieval System Online, or *MEDLARS Online*
EBSCOhost
Academic Search Complete
Springer: Springer Online Journals, Springer Science & Business Media
Research Gate
KISEP
World Wide Web: *Google Scholar, Google*

Table 2: Number of Publications in the Three Categories of the Literature Review

Categories	**No. of Literature**
Tinnitus Treatments: Current Status of TTA	22
Multiple Dimensions: DCDE multi-dimensional Assessment	29
A Decision Model: A Hierarchical Decision Model (HDM) for comprehensive TTA	21
Sum of 3 Categories	72

2.5 Multiple Dimensions of Tinnitus Treatment: DCDE

In this literature review, most studies for tinnitus treatments and their assessment are classified as application cases of two dimensions (2D), with respect to the DCDE dimensions. 1D, 3D and 4D are all less than half of 2D, as shown in Figure 5. Descriptive complementary attributes, however, are applied for 4D cases without decision models. In the gap analysis of the four dimensions of the DCDE model, the clinical evaluation dimension has a significant portion. The second largest portion is the treatment efficiency dimension, at approximately half of the clinical evaluation dimension. The diagnostic dimension is 1.33 times the duration dimension, as illustrated in Figure 6. The DCDE dimensions are detailed in Chapter 6 with the associated criteria.

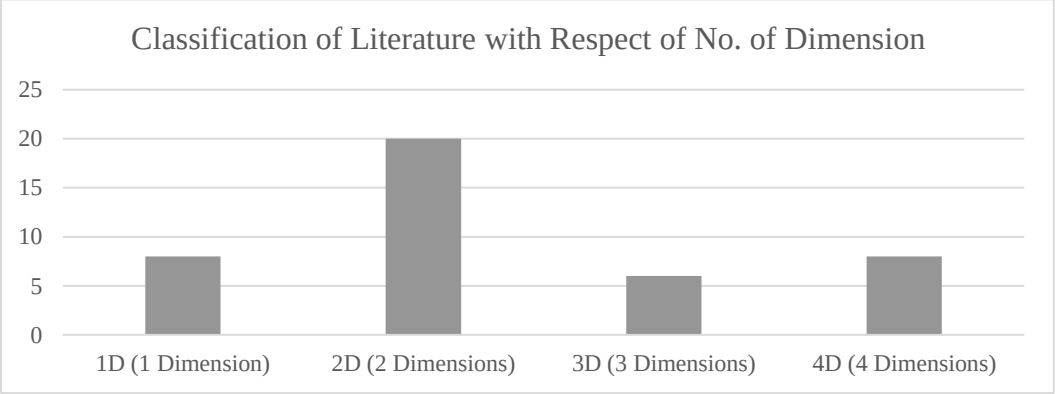


Figure 5: Classification of Dimension

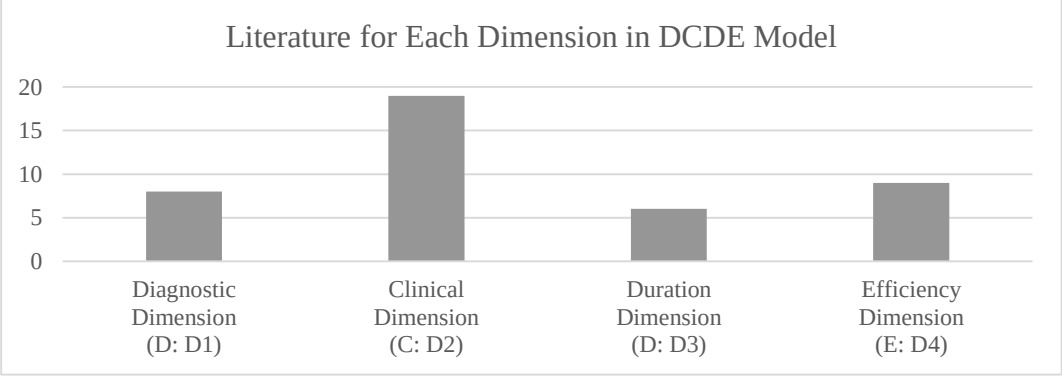


Figure 6: Proportions of Multiple DCDE Dimensions

2.6 Tinnitus Treatment Decision Models

Tinnitus management (TM) is a complex subject for multiple decision makers, among otorhinolaryngologists, audiologists, general practitioners (or primary care physicians), neurologists, psychotherapists (or psychiatrists and psychologists), pediatricians, pharmaceutical scientists, chemists, biologists, neuroscientists, pharmacists and government institutions like the National Institutes of Health (NIH), the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC) and the National Health Insurance Corporation (NHIC). Otorhinolaryngologists are the most common TTA decision makers assessing multiple criteria through specialized judgments. In particular, Korea's otorhinolaryngologists, who are clinicians for audiology and specialists for TM and TTA, may address a wide range of decision elements to compile an HDM as an applicable multi-criteria decision analysis (MCDA) method. An HDM is classified according to critical reviews among three appealing MCDA methods as summarized in Table 3.

Table 3: Summary of Popular MCDA Methods (Nasir Jamil Sheikh, 2013)

MCDA Methods	**Critical Review Elements**
Hierarchical Decision Model (HDM) / Analytic Hierarchy Process (AHP)	Criteria weights and scores are based on ratio-scale pair-wise comparisons with respect to criteria, sub-criteria and alternatives
Multi-Attribute Utility Theory (MAUT)	Illustrated overall performance of an alternative in a single nonmonetary number indicating the alternative utility
	Criteria weights are often obtained by direct surveys from stakeholders
Outranking	One option outranks another if: (1) "it outperforms the other on enough criteria of sufficient importance (as reflected by the sum of criteria weights)" and (2) "it is not outperformed by the other in the sense of recording a significantly inferior performance on any criterion"
	Another available alternatives that are codified as "incomparable"

MCDA methods are designed to evaluate each criterion and have sought to quantify the most appropriate alternatives or options. The outranking method is relatively simpler than the HDM / analytic hierarchy process (AHP) and multi-attribute utility theory (MAUT). The HDM and MAUT acquire the total scores or constant sum values of alternatives with respect to each criterion.

***The HDM and MAUT are both "compensatory" methods (Sheikh, 2013), but MAUT illustrates the overall utility value of an alternative and the HDM describes expert value judgments with weighting criteria and applies ratio-scale pair-wise comparisons (RSPC) for each criterion. For example, the ratio-scale values of four criteria with respect to a dimension can be converted to the following percentile values: C_{41}: 39%, C_{42}: 20%, C_{43}: 15% and C_{44}: 26%, totaling 100%, as illustrated in Figure 7. The HDM consists of multi-level decision elements; a hierarchical structure to prioritize or rank multiple dimensions (or D1, D2, D3, and D4, as depicted in Figure 7); and the criteria associated with each dimension under consideration of the mission, which is the overall objective. The methodology of the HDM — Mission, Objectives, Goals, Strategies and Actions (MOGSA) model — was first formulated by Dr. Kocaoglu and his following scholars with their own HDM models (Alanazi, Daim, & Kocaoglu, 2015; Amer & Daim, 2013; Chen & Li, 2011; Cleland & Kocaoclu, 1981; Gruenfeld, Mannix, Williams, & Neale, 1996; Kocaoglu, 1983; Kocaoglu, 1981; Loken, 2007; Sheikh, 2013; Kocaoglu, 2011; Sheikh, Daim, & Kocaoglu, 2011; Daim, & Gomez, 2013) and apprentices based on expert judgments (Dolan, 2008; Légaré, Ratté, Gravel, & Graham, 2008; Linstone, 1985; Lu, Madu, Kuei, & Winokur, 1994; Stasser & Stewart, 1992).

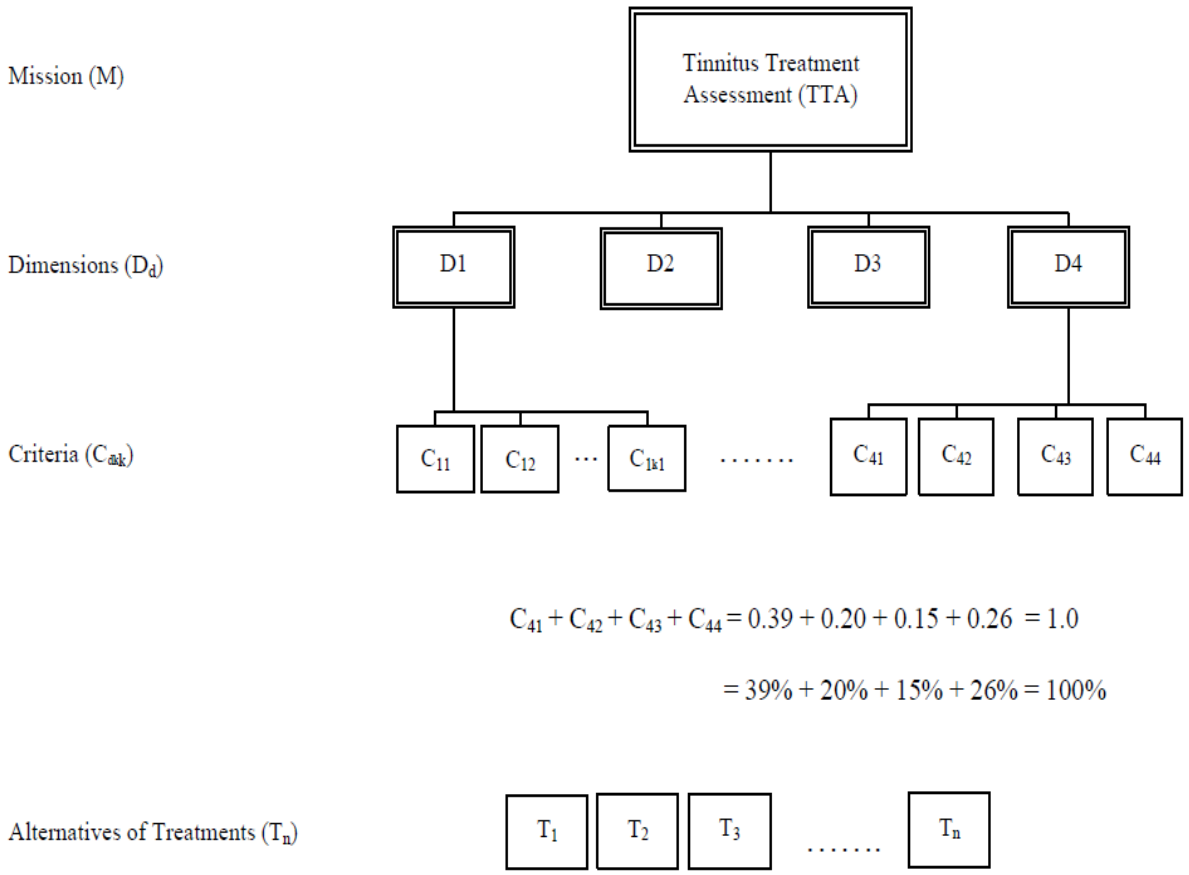


Figure 7: Example of the Ratio-scale Values of Criteria with Respect to a Dimension in an HDM for Tinnitus Treatment Assessment (TTA)

2.7 Gaps in the Literature

The gap analysis classifies the literature review papers according to the Diagnostic-Clinical-Duration-Efficiency (DCDE) model in Table 4. The results of the tinnitus review outline the multifarious criteria and sub-criteria or factors to compile a hierarchical decision-model (HDM) framework for tinnitus treatment assessment (TTA). To achieve multi-dimensional TTA and represent an outstanding alternative, the expert panel of otorhinolaryngologists with a specialty in tinnitus treatment, who are the most appropriate decision makers, may provide valuable feedback and explicit expert judgments with respect to the DCDE dimensions and the associated criteria. The gaps in number of dimension and the Diagnostic-Clinical-Duration-Efficiency (DCDE) dimensions are illustrated in Figure 8.

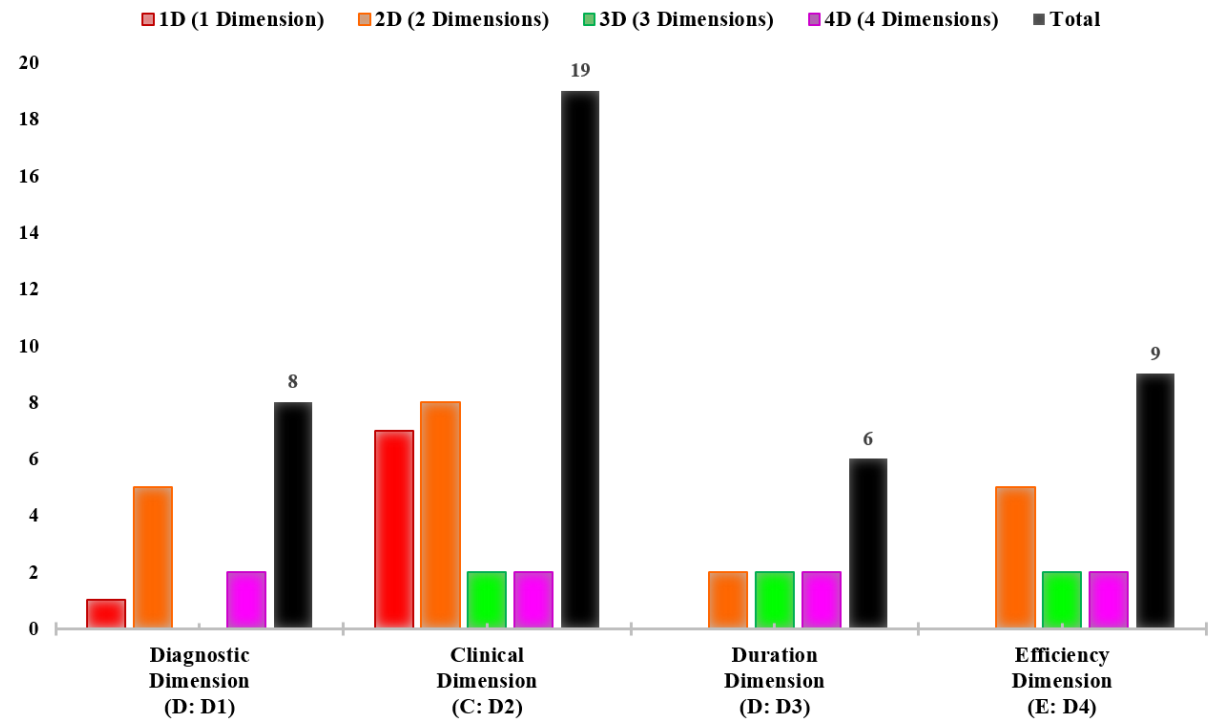


Figure 8: Gaps in the Number of Dimension and the Diagnostic-Clinical-Duration-Efficiency (DCDE) Dimensions

Table 4: Gaps in the DCDE Model with Keywords, DB and Criteria/Sub-Criteria for Tinnitus Treatment Assessment (TTA)

Title	Authors	Year	Database	Keywords	Alternative Tinnitus Treatments	Gaps of Four Dimensions (DCDE Model) (●: Applicable)				Criteria/sub-criteria for Tinnitus Treatment Assessment
						Diagnostic Dimension	Clinical Dimension	Duration Dimension	Efficiency Dimension	
Psychometric Evaluation of Visual Analog Scale for the Assessment of Chronic Tinnitus	Ilya Adamchic, Berthold Langguth, Christian Hauptmann, and Peter Alexander Tass	2012	*PubMed*	Tinnitus, Tinnitus assessment, Visual analog scale, Coordinated reset (CR), Neuromodulation, Minimal clinically identifiable difference, Receiver operating characteristic	Counseling		●			1. Visual Analog Scale
Neuroanatomical Abnormalities in Chronic Tinnitus in the Human Brain.	P. Adjamian, D. a Hall, A. R. Palmer, T. W. Allan, and D. R. M. Langers	2014	*PubMed, SicenceDirect*	Tinnitus, Voxel-based morphometry, Tractography, Gating mechanism, Limbic system Prefrontal cortex	Surgery	●		●		1. Tinnitus from Classical Pathway: Otic Tinnitus 2. Chronic Tinnitus

Treatment Response of Modified Tinnitus Retraining Therapy with Medical Therapy in the Patients with Tinnitus	Hyeon-Jin Auo, Kyung-Ho Park, Sang Won Yeo, Ki-Hong Chang, Hyeog-Gi Choi, Bong Jin Choi, Min-Ah Han and Shi-Nae Park	2009	*KoreaMed*	Tinnitus, Stress, Depression, Anxiety, Tinnitus retraining therapy	Counseling, Pharmacotherapy, Sound Therapy		●	●		1. Audiological Evaluation 2. Visual Analogue Scale 3. Treatment Effectiveness 4. Treatment Compliance
Childhood Tinnitus: Clinical Characteristics and Treatment	Seong-Cheon Bae, Shi-Nae Park, Jung-Mee Park, Min Kim, Sang-Won Yeo, and So-Young Park	2014	*SicenceDirect*	Tinnitus, Childhood Tinnitus, Clinical Characteristics, Tinnitus retraining therapy, Counseling	Counseling, Sound Therapy	●	●			1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Somatosounds (Objective Tinnitus) 3. Audiological Evaluation 4. Tinnitus Severity Evaluation

Tinnitus	David Baguley, Don McFerran, Deborah Hall Lancet	2013	*SicenceDirect*	Animals, Cognitive Therapy, Counseling, Humans, Tinnitus, Tinnitus diagnosis, Tinnitus epidemiology, Tinnitus etiology, Tinnitus physiopathology, Tinnitus psychology, Tinnitus surgery, Tinnitus therapy	Counseling, Pharmacotherapy, Sound Therapy, Surgery	•	•			1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Somatosounds (Objective Tinnitus) 3. Audiological Evaluation 4. Tinnitus Severity Evaluation 5. Psychological Evaluation
Results of TRT after Eighteen Months: Our Experience.	Baracca, Giovanna N Forti, Stella Crocetti, Andrea Fagnani, Enrico Scotti, Alberto Del Bo, Luca Ambrosetti, Umberto	2007	*CINAHL, MEDLINE*	Tinnitus, Neurophysiological model, Tinnitus retraining therapy, Counselling, Sound therapy	Counseling, Sound Therapy		•		•	1. Tinnitus Severity Evaluation 2. Treatment Effectiveness

Assessment of Psychopathological Aspects and Psychiatric Comorbidities in Patients Affected by Tinnitus.	Seyda Belli, Hasan Belli, Talat Bahcebasi, Adnan Ozcetin, Emrehan Alpay, Umit Ertem	2008	*EBSCOhost, Academic Search Complete, Springer Online Journals*	Tinnitus, Psychiatric comorbidity, Anxiety, Depression, Somatization	Counseling	●	●			1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Psychological Evaluation 3. Tinnitus Severity Evaluation
Design and Evaluation of Tinnitus Synthesis Methods: from Spectral to Spatial Matching.	Stéphanie Bertet, Alexis Baskind, Alain Londero, Laure Bonfils, Isabelle Viaud-Delmon, Olivier Warusfel	2013	*EBSCOhost, Academic Search Complete*	Tinnitus, Tinnitus Synthesis, VAS (Visual analogue scale)	Sound Therapy		●			1. Visual Analogue Scale 2. Audiological Evaluation

Simvastatin and Ginkgo Biloba in the Treatment of Subacute Tinnitus: A Retrospective Study of 94 Patients.	Martin Canis, Bernhard Olzowy, Christian Welz, Markus Suckfüll, Klaus Stelter	2011	*ResearchGate, PubMed*	Tinnitus, Subacute tinnitus, Simvastatin, Ginkgo biloba	Pharmacotherapy		●	●	●	1. Chronic Tinnitus 2. Acute Tinnitus 3. Tinnitus Severity Evaluation 4. Treatment Effectiveness 5. Treatment Compliance
Drug Treatments for Tinnitus.	Cynthia L. Darlington and Paul F. Smith	2007	*PubMed*	Tinnitus, Drug treatments, Gentamicin, Steroids, Anticonvulsants, Benzodiazepines	Pharmacotherapy	●			●	1. Subjective Tinnitus 2. Treatment Effectiveness

Pharmacological Approaches to Tinnitus Treatment	Ana Belén Elgoyhen and Berthold Langguth	2011	*Springer Science & Business Media*	Tinnitus, Phantom sound, Lidocaine, Neramexane, Hearing, Noise trauma	Pharmacotherapy		●	●	●	1. Chronic Tinnitus 2. Acute Tinnitus 3. Audiological Evaluation 4. Tinnitus Severity Evaluation 5. Treatment Effectiveness
Directing Neural Plasticity to Understand and Treat Tinnitus	Navzer D. Engineer, Aage R. Møller, Michael P. Kilgard	2013	*PubMed*	Tinnitus, Vagus nerve stimulation (VNS), Treatment of chronic tinnitus	Sound Therapy		●			1. Audiological Evaluation
Tinnitus Patients Lost to Follow-up.	Stella Forti, Umberto Ambrosetti, Andrea Crocetti, Luca Del Bo	2010	*PubMed*	Tinnitus, Tinnitus retraining therapy (TRT)	Counseling, Sound Therapy		●			1. Audiological Evaluation 2. Tinnitus Severity Evaluation 3. Treatment Effectiveness

A Systematic Review and Meta-Analysis of Randomized Controlled Trials of Cognitive–Behavioral Therapy for Tinnitus Distress	Hugo Hesser, Cornelia Weise, Vendela Zetterqvist Westin, Gerhard Andersson	2011	*PubMed, ResearchGate*	Tinnitus, Cognitive–behavioral therapy, Efficacy, Meta-analysis	Counseling		●			1. Tinnitus Severity Evaluation 2. Psychological Evaluation
Systematic Review and Meta-Analyses of Randomized Controlled Trials Examining Tinnitus Management Derek	Derek J. Hoare, Victoria L. Kowalkowski, Sujin Kang, Deborah A. Hall	2011	*PubMed*	Tinnitus, Good Practice Guidelines, UK Department of Health, Cognitive behavioral therapy, Tinnitus retraining therapy, Randomized controlled trial	Counseling, Sound Therapy, Pharmacotherapy		●			1. Tinnitus Severity Evaluation 2. Psychological Evaluation

Surgical Treatment of Spontaneous Meningocele of the Temporal Bone Causing a Pulsatile Tinnitus	Han Dong Kang, Sun Min Park, Sae Young Kwon and Chang Woo Kim	2011	*KISEP, Google Scholar*	Meningocele, Pulsatile tinnitus, Temporal bone	Surgery		●		●	1. Audiological Evaluation 2. Tinnitus Severity Evaluation 3. Treatment Effectiveness
Tinnitus in Patients with Profound Hearing Loss and the Effect of Cochlear Implantation	Dong-Kee Kim, Seong-Cheon Bae, Kyoung-Ho Park, Beom-Cho Jun, Dong-Hee Lee, Sang Won Yeo, Shi-Nae Park	2013	*PubMed, Springer*	Cochlear implantation, Profound hearing loss, Tinnitus	Surgery		●		●	1. Audiological Evaluation 2. Visual Analogue Scale 3. Tinnitus Severity Evaluation 4. Treatment Effectiveness
Tinnitus in Patients with Chronic Otitis Media Before and After Middle Ear Surgery	Dong-Kee Kim, Shi-Nae Park, Min Ji Kim, Se Yun Lee, Kyoung-Ho Park, Sang Won Yeo	2011	*PubMed, Springer*	Tinnitus, Chronic otitis media, Middle ear surgery	Surgery		●		●	1. Audiological Evaluation 2. Visual Analogue Scale 3. Tinnitus Severity Evaluation 4. Treatment Effectiveness

Large Nasopharyngeal Inverted Papilloma Presenting with Rustling Tinnitus	Masahiro Kishikawa, Atsunobu Tsunoda, Yoji Tanaka, Seiji Kishimoto	2014	*MEDLINE, CINAHL, ScienceDirect*	Tinnitus, Rustling tinnitus, Nasopharyngeal inverted papilloma, Tumor	Surgery	●				1. Somatosounds (Objective Tinnitus)
Prognosis of Tinnitus After Acoustic Neuroma Surgery — Surgical Management of Postoperative Tinnitus	Michihiro Kohno, Masanobu Shinogami, Hidehiko Yoneyama, Osamu Nagata, Shigeo Sora, Hiroaki Sato	2014	*MEDLINE, ScienceDirect*	Acoustic neuroma, Neurinoma, Surgery, Tinnitus, Vestibular schwannoma	Surgery		●			1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Audiological Evaluation 3. Tinnitus Severity Evaluation 4. Treatment Effectiveness

Tinnitus: Causes and Clinical Management	Berthold Langguth, Peter M Kreuzer, Tobias Kleinjung, Dirk De Ridder	2013	*MEDLINE, ResearchGate*	Tinnitus, Diagnostic and therapeutic management, Treatments for management of tinnitus	Counseling, Sound Therapy, Pharmacotherapy	●	●	●	●	1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Somatosounds (Objective Tinnitus) 3. Audiological Evaluation 4. Tinnitus Severity Evaluation 5. Psychological Evaluation 6. Treatment Effectiveness 7. Treatment Compliance
Current Trends in the Treatment of Subjective Tinnitus at University Hospitals in Korea	Shin Young Yoo, Tae Su Kim, In Seok Moon, Shi-Nae Park, Jung Eun Shin, Ho-Ki Lee, Gi Jung Im, Jeong Hun Jang, Eun-Ju Jeon, Seung Hyo Choi, Jeong Hwan Choi, June Choi, Kyung Wook Heo, Dong Gu Hur and Eui-Cheol Nam	2013	*KoreaMed*	Korea, Questionnaire, Tinnitus, Treatment	Counseling, Sound Therapy, Pharmacotherapy	●	●	●	●	1. Sensorineural Tinnitus (Subjective Tinnitus) 2. Visual Analogue Scale (VAS) 4. Tinnitus Severity Evaluation 5. Psychological Evaluation 6. Chronic Tinnitus 7. Acute Tinnitus 8. Treatment Cost 9. Treatment Effectiveness

2.8 Conclusion

2.8.1 Literature Review: Motivation of Research

The goal of this literature review is to comprehend the definition of tinnitus, its trends (or the current prevalence of tinnitus), treatment management (TM), available tinnitus treatments and TTA with medical background based on the specialized feedback from the expert panel. To establish a literature library with the most appropriate tinnitus papers and credible authors, the following questions (Baguley et al., 2013) are addressed with otorhinolaryngologists specialized in tinnitus treatments (Table 5).

Table 5: Specific Questions to Build Literature Libraries

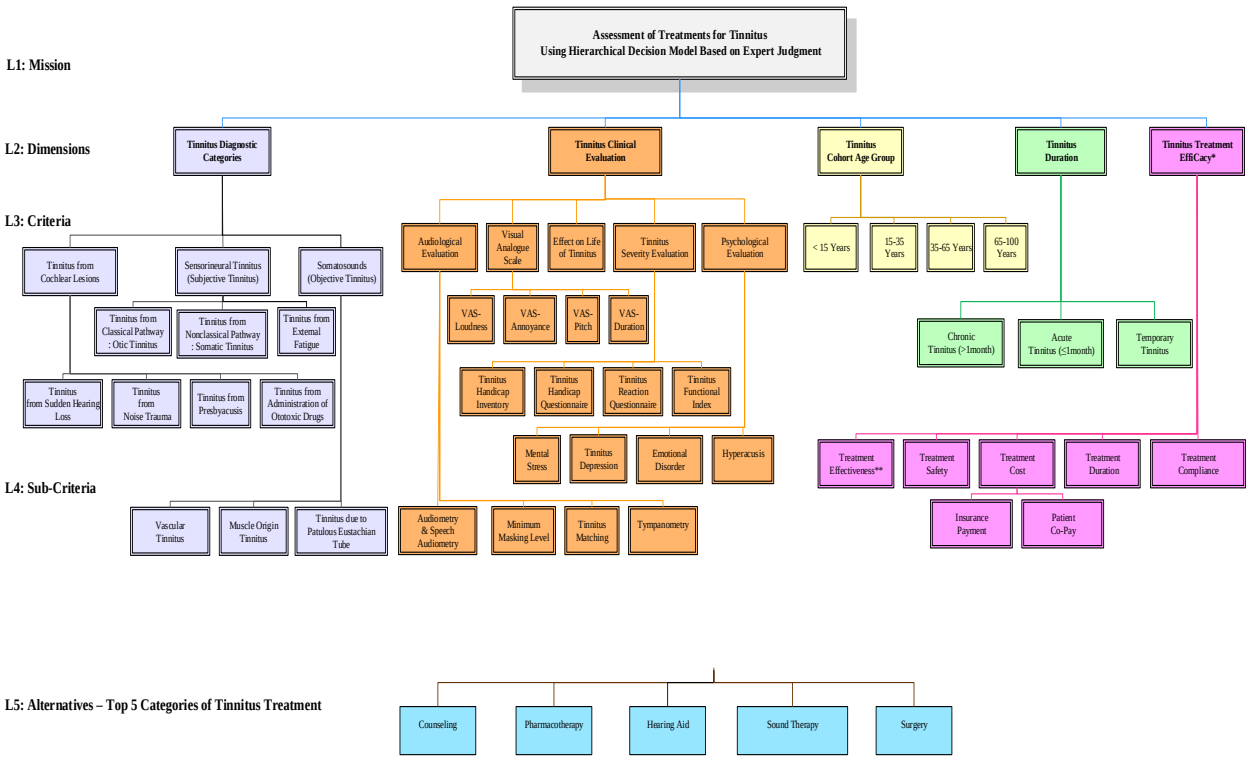
Subjects	Specific Questions
Problems	1. How complex are the pathologies of tinnitus and the reasons for "no cure" for globally prevalent tinnitus so far? 2. What are the most uncertain problems for tinnitus treatment assessment (TTA)?
Strategies / Management	3. What strategies of TM are applicable with respect to safety, effectiveness, cost and compliance compared to the current treatment model? 4. Where is the proposition for the comprehensive TM to fulfill a wide range of requirements of decision makers for TTA?
Robustness	5. What tinnitus treatments or therapies are available for the "evidence-based" evaluation?
Integration	6. Which kind of multidisciplinary cooperation is persuasive to improve TM and attributes for TTA? 7. Who is the most appropriate coordinator to facilitate the collaborative work with different stakeholders or decision makers for TTA?
Decision Model / Expert Panel	8. How many practices using a decision model for TTA are accessible? 9. What decision models are feasible for TTA? 10. Who are the populations with certified specialties in tinnitus treatment to organize the expert panel for TTA in the Republic of Korea?

The mission of comprehensive TTA is the cornerstone to resolving the questions that specify research interests. The contemplated attributes of TTA foster the identification of multiple DCDE dimensions and the criteria associated with each dimension. The three categories and five step

process of the literature review are designed to ascertain the gaps in the DCDE dimensions for multidimensional tinnitus treatment assessment using an HDM. A gap analysis of the literature can cultivate the body of knowledge under consideration of the research methodology of multi-criteria decision analysis (MCDA) with respect to the four diagnostic, clinical, duration and efficiency dimensions.

2.8.2 Development of Initial and Intermediate MCDA

To build the criteria associated with each dimension, the obtained body of knowledge can be expanded into new contexts of multilevel criteria with sub-criteria or factors. The initial and intermediate multi-criteria decision analysis (MCDA) is flexible, allowing for the adaptation of new criteria, sub-criteria and alternatives for multifaceted decision makers. This MCDA framework is valuable to visualize the conceptual approaches to assess alternative tinnitus treatments and their multilevel attributes. In particular, diagnostic categories, clinical evaluation and the efficiency domain of treatments provide complications for contextualization in the MCDA. Studies of literature review provide the applicable libraries to compile abundant criteria and surplus factors with respect to each dimension and represent the most appropriate tinnitus treatment with comparisons of alternative tinnitus treatments using the initial MCDA. For example, the feedback of the expert panel represents the immense complexity of the initial and intermediate MCDA framework that may turn out to exceed the capacity of the research instrument for expert judgments, as illustrated in Figure 9.



* Treatment Efficacy : Criteria based on factors such as Safety, Effectiveness, Cost, Time and Compliance

**Treatment Effectiveness : Curative influence of alternate tinnitus treatments such as counseling, pharmacotherapy, hearing aid, Sound Therapy(including Acoustic Stimulation and Music Therapy) and surgey.

Figure 9: Example of the Initial MCDA Framework for Tinnitus Treatment Assessment Using a Hierarchical Decision Model Diagram

2.8.3 Institution of the Decision Model

The main objective of instituting a decision model is to obtain the ascertained insights with respect to: the current treatment assessment, the decision model framework, the gap analysis of the literature review, and the reliable medical evaluations with existing studies. To qualify the options of the decision models, the substantial requirements are addressed by their adaptability and compatibility with comprehensive decision elements: the mission; multiple dimensions; multifaceted criteria; and accessibility to decision makers. For instance, otorhinolaryngologists are exclusive decision makers for tinnitus treatment assessment (TTA) in the Republic of Korea, and

there are a wide range of decision makers for tinnitus management (TM). The guidance and operation of assessment are significant functions of decision models with respect to the multiple DCDE dimensions. Thus, the organization of an expert panel of otorhinolaryngologists specializing in tinnitus treatment is a requisite for implementing a decision model based on value judgments. Furthermore, the interview-based verbal survey is more accessible than other approaches — mobile, postal and email surveys — to operationalize the decision model for TTA.

2.8.4 Research Gaps

To ascertain the gaps in tinnitus treatment assessment (TTA), the multiple DCDE dimensions represent the biased existing researches, as illustrated in Figure 10. Clinical evaluation (D2) has a substantial role in the DCDE dimensions for TTA in most studies. The three dimensions of diagnostic (D1), duration (D3), and efficiency (D4) are involved to a greater or lesser extent. For example, D4 is the second largest proportion but is still less than half of D2; D1 is the third largest fraction; and D3 is the smallest dimension. The reviewed medical papers tend to focus more heavily on the clinical evaluation dimension (D2). In the most outstanding D2, one and two dimensional (1D and 2D) studies are dominant, as illustrated in Figure 10. The classification of number of dimensions reveals the largest portion of combined dimensional (2D) studies: (1) Diagnostic and Clinical (DC: D1 & D2) and (2) Clinical and Efficiency (CE: D2 & D4). The classified papers about all-inclusive four DCDE dimensions (4D) are less than half of 2D-TTA papers, and the 4D-TTA papers traditionally use a descriptive analysis without decision models, or value judgments and the particular criteria associated with each dimension. The detailed criteria are applicable for both TM and TTA.

In tinnitus management (TM), MCDA methods are novel decision making approaches. Critical reviews classify an HDM or an analytic hierarch process (AHP) into three appealing MCDA methods. A literature review provides the manifold applications of HDM, but there is no one hierarchical decision model (HDM) of MCDA methods that is used for tinnitus treatment assessment. Furthermore, some AHP models have been applied to gastrointestinal bleeding diagnosis and colorectal cancer screening decision aid studies (Dolan, 2008). In particular, the comprehensive tinnitus treatment assessment (TTA) contrasts and competes with alternative tinnitus treatments such as counseling, pharmacotherapy, sound therapy and surgery. A medical decision model for TTA uses multilevel decision elements, which has been tested for its verification and validation.

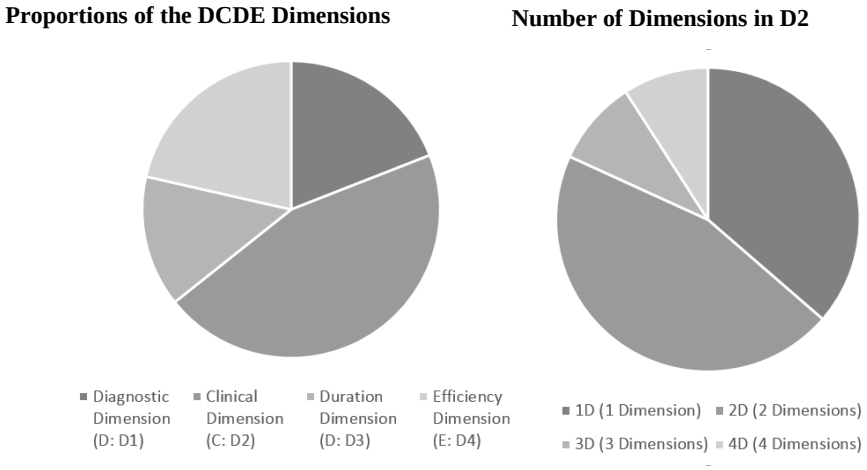


Figure 10: Proportions of the DCDE Dimensions and the Classification of the Number of Dimensions in a Clinical Evaluation Dimension (D2)

2.8.5 Proposal of Research

The disparate gaps in current treatment assessments for tinnitus and related disorders can be ameliorated by a novel multilevel decision model. The medical decision model for TTA allows the application of a hierarchical decision model (HDM) using multiple DCDE dimensions with expert judgments. An HDM enables us to address the relative rankings of tinnitus treatments. The decision elements at multiple levels are ranked with respect to the top level (L1): the mission, the second level (L2): the multiple DCDE dimensions, the third level (L3): the multifarious criteria, and the bottom level (L4): the alternatives of tinnitus treatments, as illustrated in Figure 11. The alternatives consist of four candidate tinnitus treatments — counseling, pharmacotherapy, sound therapy and surgery — to address the most outstanding tinnitus treatment as a top-ranked alternative.

The multidimensional TTA methodology is instituted by seven major phases, as follows:

(1) Developing the multiple dimensions and criteria
(2) Building and verifying the hierarchical decision model (HDM) frameworks for multiple dimensions, criteria and sub-criteria or factors
(3) Establishing and validating an HDM with respect to the DCDE dimensions and criteria associated with each dimension
(4) Organizing an HDM expert panel

(5) Designing and Completing the HDM research instrument to acquire the relative rankings of each dimension, criterion and alternatives based on quantified expert judgments

(6) Analyzing the relative rankings and treatment values (TVs)

(7) Compiling the HDM gap analysis (HDM-GA)

All phases listed above are detailed and described in Chapter 4.

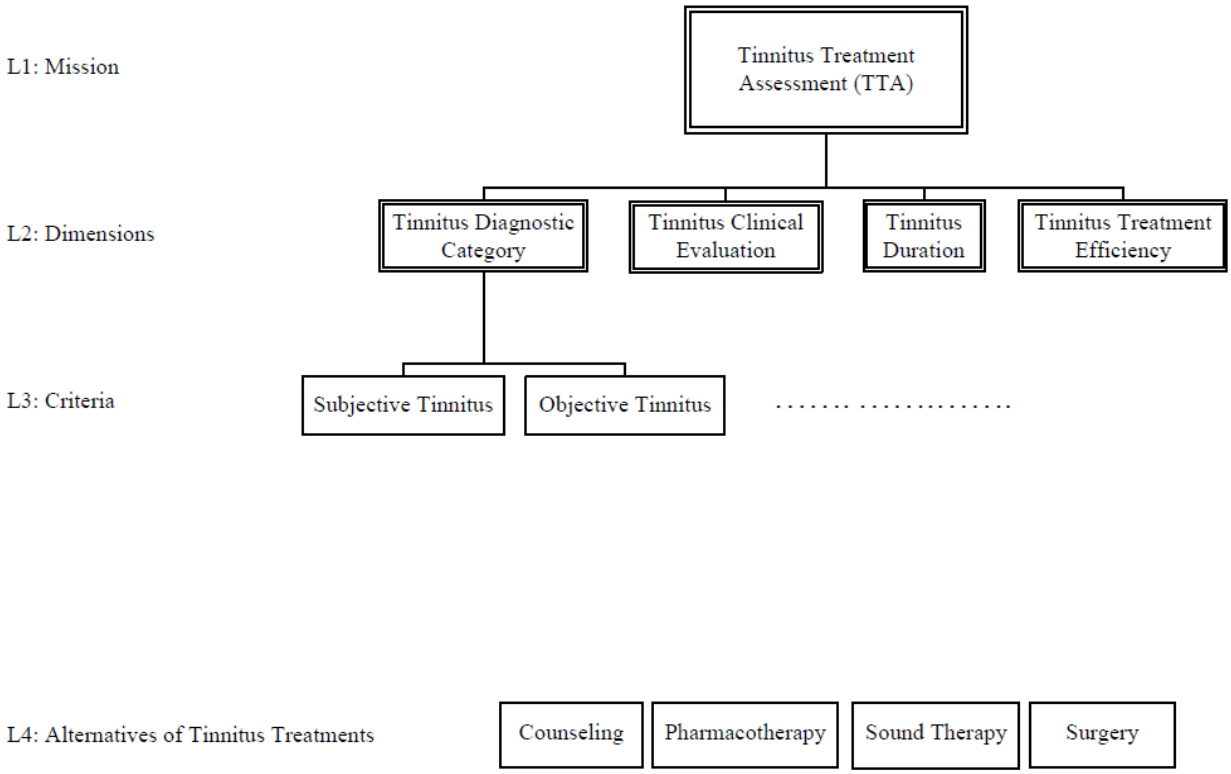


Figure 11: Example of Decision Analysis Framework for Tinnitus Treatment Assessment (TTA)

Chapter 3

Descriptive Value of Multiple Dimensions

To comprehend the value of multiple dimensions, the following treatment values (TV_{dn}) of an HDM (Figure 12) foster the description and a better understanding for multi-criteria decision analysis (MCDA), as shown in Table 6.

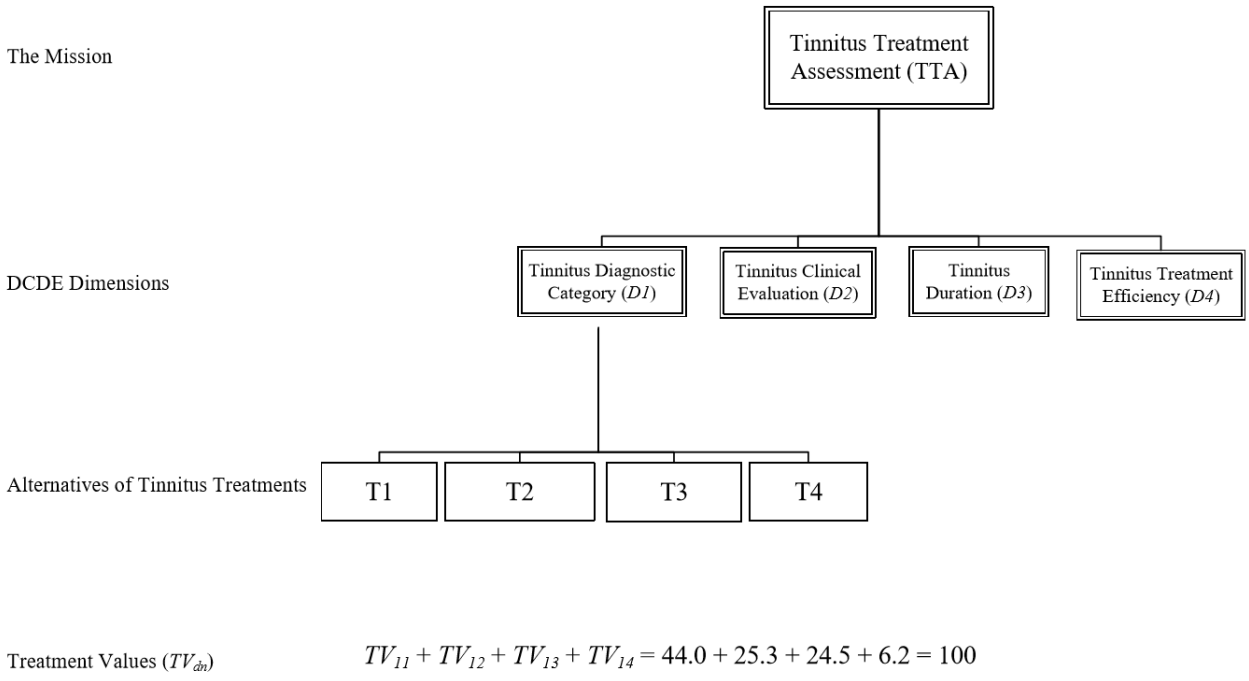


Figure 12: Example of an HDM with Treatment Values **(TV_{dn})** of Alternative Tinnitus Treatments with Respect to Multiple Dimensions

Table 6: Values of Multiple Dimensions Using an HDM

Decision Elements of an HDM	**Values of Multiple Dimensions**
A Mission / Dimensions / Alternatives	• According to the TTA with the DCDE dimensions, the four alternative tinnitus treatments (or T1, T2, T3 and T4) are classified. An "outstanding treatment" presents the top treatment value (*TV*), ranging from 0 to 100, which totals a constant sum of 100 for each dimension. • For instance, the treatment values (TV_{dn}) of a diagnostic dimension (*D1*) with respect to the mission may turn out to be TV_{11}: 38.2, TV_{12}: 24.5, TV_{13}: 14.5 and TV_{14}: 22.8, totaling 100, as illustrated in Figure 11. The highest, TV_{11}, represents that T1 is an "outstanding treatment" with respect to *D1*. • If there is no "outstanding treatment" concerning multiple dimensions, the development of additional criteria or alternatives will improve the gaps in the DCDE dimensions. • Furthermore, the total TV_n aggregates the relative importance of each dimension to consider the gaps in the DCDE dimensions. The detail equations for TV_n are illustrated in Chapter 4.
Criteria	• An HDM has been applied to the expert value judgments with each criterion with respect to multiple dimensions, as well as

	deriving the ratio-scale pair-wise comparisons (RSPC) for each criterion. For example, the values (Z_{dkn}) of the ratio-scale relative importance of four alternative tinnitus treatments (or T1, T2, T3 and T4) with respect to the first criterion (C41) associated with the fourth dimension (D4) may turn out to be Z_{411}: 0.38, Z_{412}: 0.25, Z_{413}: 0.27 and Z_{414}: 0.10: which total 1.00, as illustrated in Figure 13. The highest, Z_{411}, represents that T1 is an "outstanding treatment" with respect to a criterion of *C41*.The detailed definitions of dimensions, criteria and alternatives will be described in Chapter 6. • The ratio values (Z_{dkn}) can be converted to percentile values such as T1: 38%, T2: 25%, T3: 27% and T4: 10%, which are the ranking values of TTA with respect to *C41*, totaling a constant sum of 100%, as shown in Figure 14. The detailed calculations of Z_{dkn} will be illustrated in Chapter 4. • The relative ranking values of alternative tinnitus treatments regarding a specific criterion associated with each dimension denote the specialized evaluation outcomes for TTA decision makers such as otorhinolaryngologists. These outcomes may motivate the multifaceted decision makers to foster the multidimensional decision analysis for TTA.

	• Furthermore, for the improvement of tinnitus management (TM), the all-inclusive DCDE model is informative to multi-disciplinary decision makers: otorhinolaryngologists, primary care physicians (or general practitioners), audiologists, neurologists, pediatricians, psychotherapists (or psychiatrists and psychologists), pharmaceutical scientists, chemists, biologists, neuroscientist, pharmacists, as well as government institutions: National Institutes of Health (NIH), the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and prevention (CDC) and the National Health Insurance Corporation (NHIC).

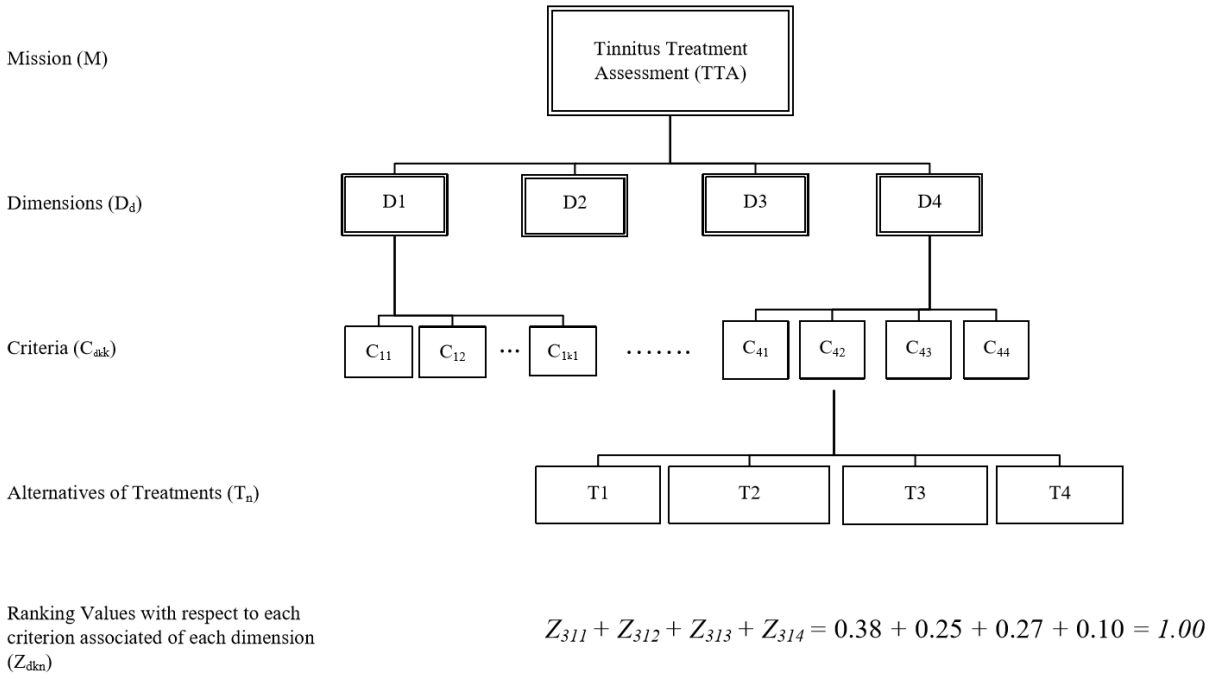


Figure 13: Example of Ranking Values of Alternative Tinnitus Treatments with Respect to Multiple Dimensions in an HDM

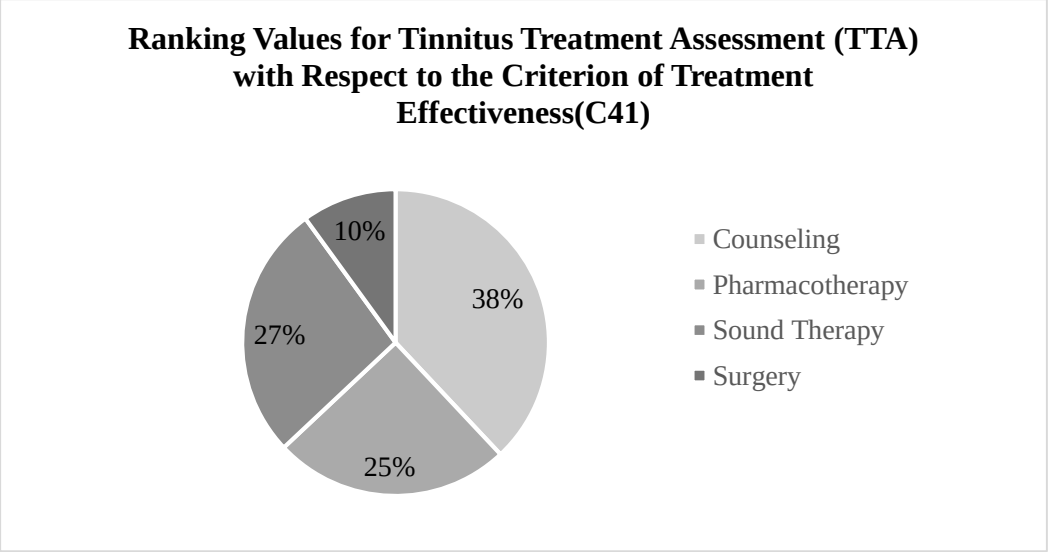


Figure 14: Example of Ranking Values for Tinnitus Treatment Assessment (TTA) with Respect to the Criterion of Treatment Effectiveness (C41) Associated with the Efficiency Dimension (D4)

Chapter 4

Research Strategy

4.1 Purpose of Research: Motivation

The purpose of this research is to perform a case study using the initial and intermediate HDM frameworks for comprehensive tinnitus treatment assessment (TTA) with qualified decision makers: Korea's otorhinolaryngologists with a specialty in tinnitus. The HDM using multiple dimensions is applicable for TTA based on expert judgments. This study may foster novel decision analysis approaches for an improved TTA.

The case studies include a framework of decision modeling, pair-wise comparison analysis, and tinnitus treatment values (TVs) based on relative ranking appraisals. To identify the most appealing features of tinnitus treatments, a five-step process and three categories of literature review have been attempted in Chapter 2.

This dissertation research involves the literature review to comprehend the definition of tinnitus, the trends of tinnitus (or current prevalence of tinnitus), tinnitus management (TM), available tinnitus treatments and TTA with medical background based on the specialized feedback from the expert panel. The networking process, employed to organize the expert panel with main decision makers, is helpful to establish literature libraries with trustworthy authors and the most appropriate papers about tinnitus recommended by those experts. The following is a questionnaire for TTA:

- How complicated are the pathologies of tinnitus and the reasons of “no cure” for globally prevalent tinnitus so far?
- What are the most uncertain problems for tinnitus treatment assessment (TTA)?
- What strategies of TM are applicable with respect to safety, effectiveness, cost and compliance, compared to the current treatment assessment?
- Where is the proposition for comprehensive TM to fulfill the wide range of requirements from the decision makers for TTA?
- What tinnitus treatments or therapies are available for an “evidence-based” evaluation?
- Which kind of multidisciplinary cooperation is persuasive to improve TM and attributes for TTA?
- Who is the most appropriate coordinator to promote the collaborative work with multifarious stakeholders or decision makers for TTA?
- How many practices using the decision model for TTA are accessible?
- What decision models are feasible for TTA?
- Who are the populations with certified specialties in tinnitus treatments to organize the expert panel for TTA in the Republic of Korea?

These questions address this dissertation research interests: the current prevalence of tinnitus and Korea’s patients who are suffering with severe tinnitus, as this severe tinnitus reduces their QOL substantially.

4.2 Research Questions

The contemplated attributes of TTA foster the identification for multiple dimensions and the criteria associated with each dimension. To ascertain gaps in the dimensions, the review of the literature cultivates the research questions as follows:

(1) What are the attributes necessary to design a treatment assessment model with multiple dimensions and the associated criteria?

(2) Where is the feasible position of this decision model to evaluate tinnitus treatments with physicians and multidisciplinary researchers?

(3) How can otorhinolaryngologists use this multidimensional tinnitus treatment assessment for their reinforced decision-making process and a more confident clinical standard?

4.3 Research Methodology: Hierarchical Decision Model (HDM)

A hierarchical decision model (HDM) with expert judgments is applicable to compile a comprehensive TTA with the four DCDE dimensions. MCDA methods are designed to evaluate each criterion and quantify the decision options or alternatives. In particular, an HDM among multi-criteria decision analysis (MCDA) methods may be an innovative approach in the research category of tinnitus and TTA. Furthermore, an HDM can reveal the relative rankings of tinnitus treatments. The features of an HDM consist of a hierarchical structure. The decision element levels include: the mission, which is the overall objective, multiple dimensions, the criteria associated with each dimension and alternatives or decision options. The research methodology of the HDM can be considered in seven major phases, as illustrated in Figure 15.

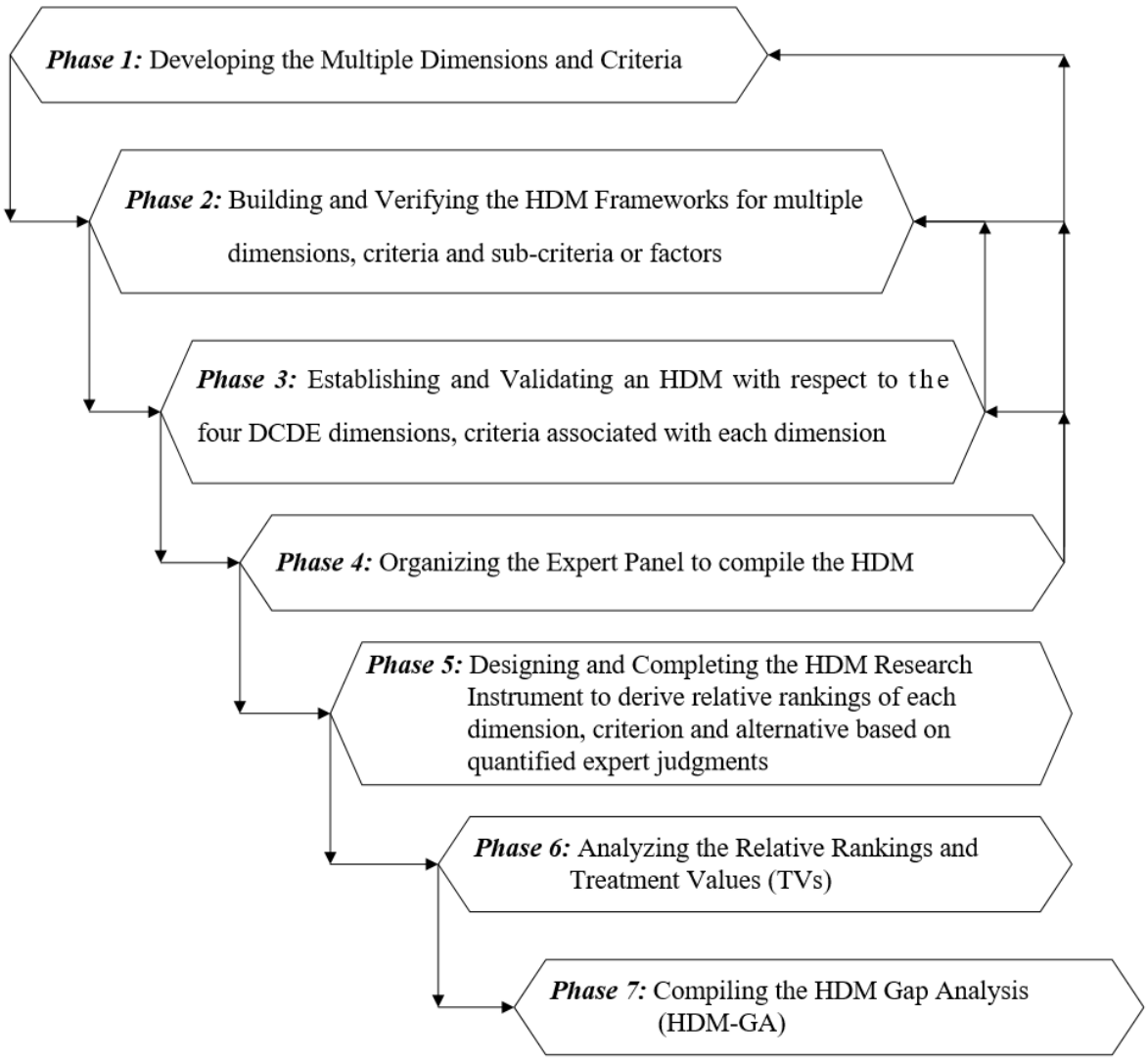


Figure 15: Seven-phase Process of the HDM for TTA

4.3.1 Phase 1: Developing the Multiple Dimensions and Criteria

Multi-level decision elements have been applied for a comprehensive decision analysis using the HDM for the specific research objectives, as illustrated in Figure 16. The first HDM phase includes a literature review that ameliorates the development of the decision elements: the mission, the

multiple DCDE dimensions, the criteria and the sub-criteria or the factors, as summarized in Table 7.

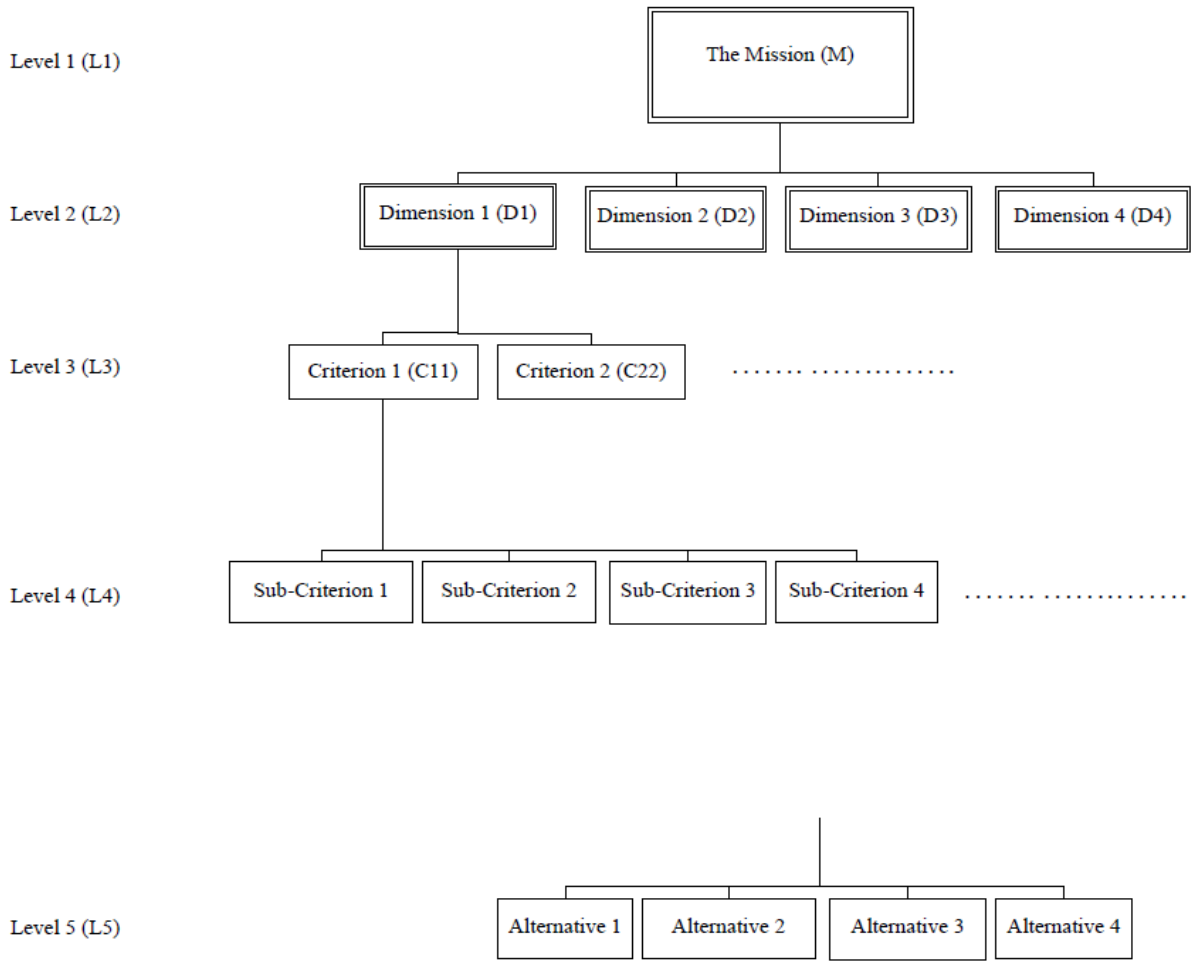


Figure 16: Multi-level Decision Elements in the HDM

Table 7: Development of the Decision Elements

Element	Summary
The Mission	• The definite objective of a hierarchical decision model (HDM) • The topmost level (L1) decision element: A cornerstone of the HDM
Dimensions	• The four dimensions (or D1, D2, D3 and D4) • The second level (L2) decision elements • The Multiple DCDE dimensions: tinnitus diagnostic category; tinnitus clinical evaluation; tinnitus duration; and tinnitus treatment efficiency • The multifaceted worldviews (or multiple perspectives) of decision makers for the management of tinnitus (or tinnitus management: TM); or of all-inclusive stakeholders such as otorhinolaryngologists, audiologists, general practitioners (or primary care physicians), neurologists, psychotherapists (or psychiatrists and psychologists), pediatricians, pharmaceutical scientists, chemists, biologists, neuroscientist, pharmacists and government institutions: National Institutes of Health (NIH), the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and prevention (CDC) and the National Health Insurance Corporation (NHIC) for TM

Criteria	• Multifarious criteria associated with each dimension • The third level (L3) decision elements: The high-level (or upper level) requirements for the assessment of alternatives • For instance, there are the criteria 1 and 2 (C11 and C12) associated with the first dimension (D1). C11 encompasses the compound of the factors or the sub-criteria, as illustrated in Figure 16.
Sub-Criteria or Factors	• The wide range of sub-criteria or factors associated with each criterion: the factors that can be compromised on hierarchical layers or eliminated according to the capability of research instrument in the HDM without sub-criteria, as illustrated in Figure 17. • The fourth level (L4) decision elements: The detail (or lower level) requirements for the evaluation of each alternative • The factors consist of an HDM criterion • Figure 17 presents the sub-criteria 1, 2, 3 and 4, which are associated with the first criterion (C11) with respect to the first dimension (D1).

Alternatives	• The four decision options or tinnitus treatment alternatives: T1, T2, T3 and T4 • The bottom level (or fifth level: L5) in decision elements • The ratio-scale pair-wise comparisons (RSPC) based on expert judgments about the alternative tinnitus treatments like counseling, pharmacotherapy, sound therapy and surgery with respect to criteria and sub-criteria or factors

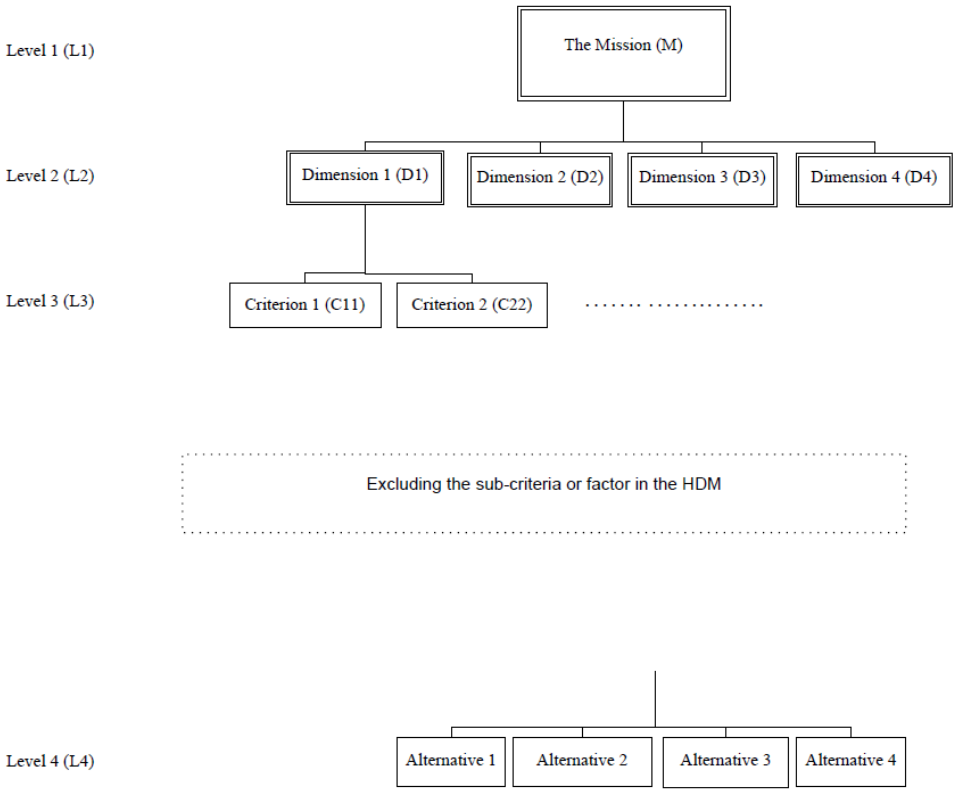


Figure 17: HDM without the Sub-Criteria or Factors

4.3.2 Phase 2: Building the Initial HDM Framework

The second phase of HDM is designed to build and verify the initial and intermediate HDM (i-HDM) frameworks for the multiple dimensions and a wide range of criteria with multifaceted sub-criteria or factors (Figures 18, 19 and 20). To institute each criterion, specific factors are developed. An HDM criterion synthesizes a set of sub-criteria or factors. In this phase, the factors are increased exponentially and revised simultaneously to ameliorate and develop the i-HDM frameworks to build a robust, verified HDM (v-HDM) framework, as detailed in the following session 4.3.3.

Hierarchical Decision Model Diagram
(Ver. 1)

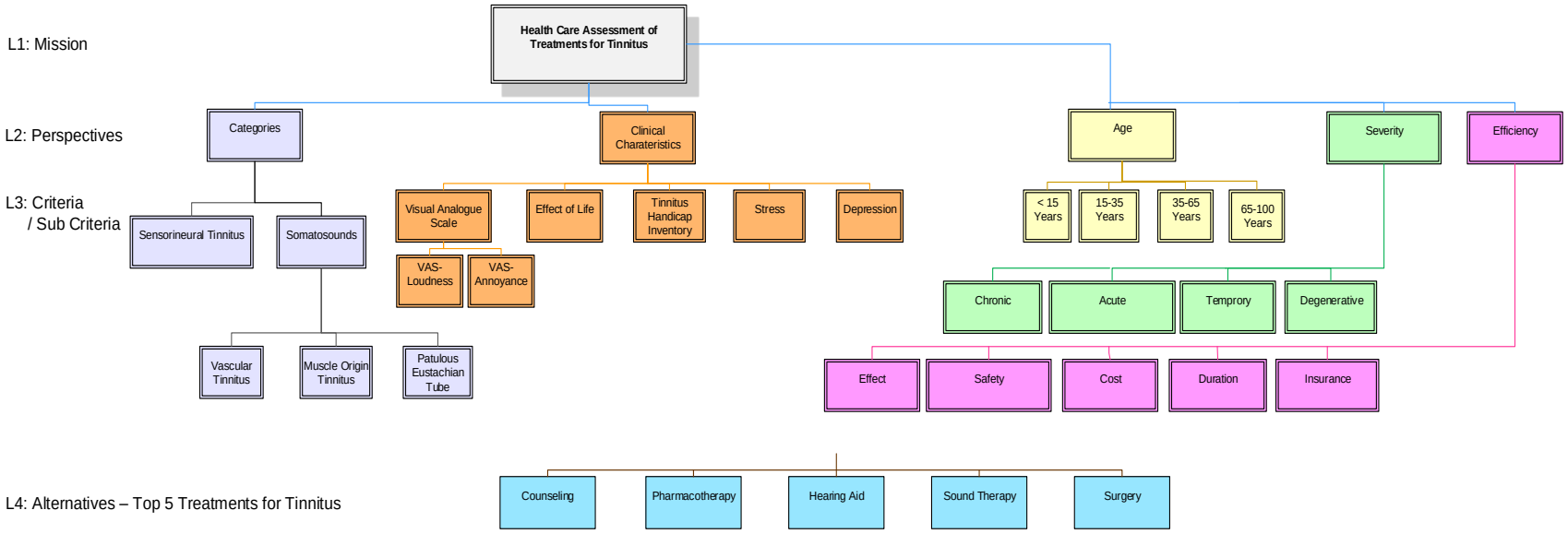


Figure 18: Example of an Initial Hierarchical Decision Model (i-HDM) Framework (Version 1.0)

Hierarchical Decision Model Diagram
(Ver. 2)

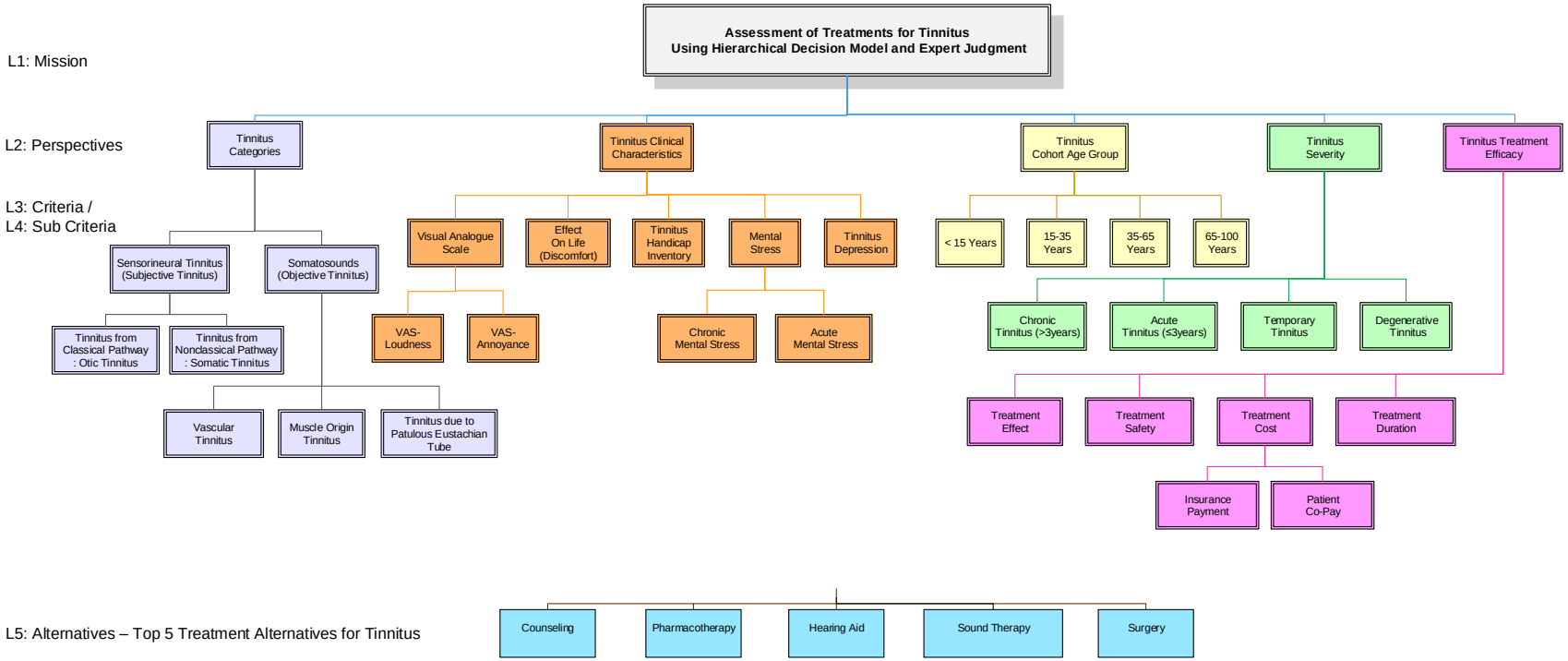
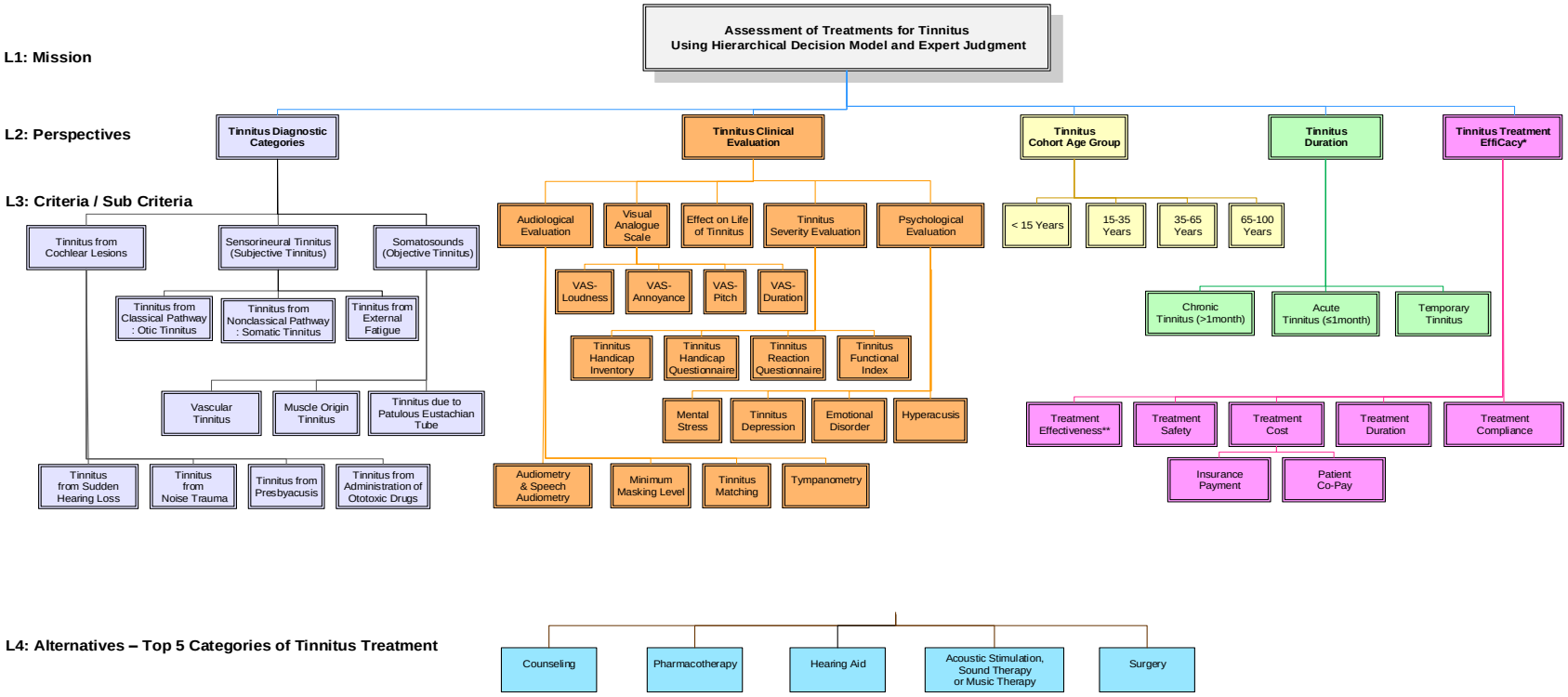


Figure 19: Example of an Intermediate HDM Framework (Version 2.0)

Hierarchical Decision Model Framework (Ver.3)



*Treatment Efficacy : Ability to produce a desired amount of desired treatment performance index(Safety, Effectiveness, Cost, Time and Compliance)
**Treatment Effectiveness : The degree to treatment achieves results of favorable turn and complete recovery.

Figure 20: Example of an Intermediate HDM Framework (Version 3.0)

4.3.3 Phase 3: Building the HDM

In this third phase, the established HDM denotes the verified HDM (v-HDM) Framework.

The feedback of the initial expert panel on the initial HDM (i-HDM) frameworks fosters the development of the v-HDM. The v-HDM is a compromise on a set of multi-layered decision elements confirmed by expert appraisals. The wide range of detailed sub-criteria are eliminated to compile the research instrument for expert judgments in the process of the v-HDM. For instance, there is a v-HDM without sub-criteria, as illustrated in Figure 21.

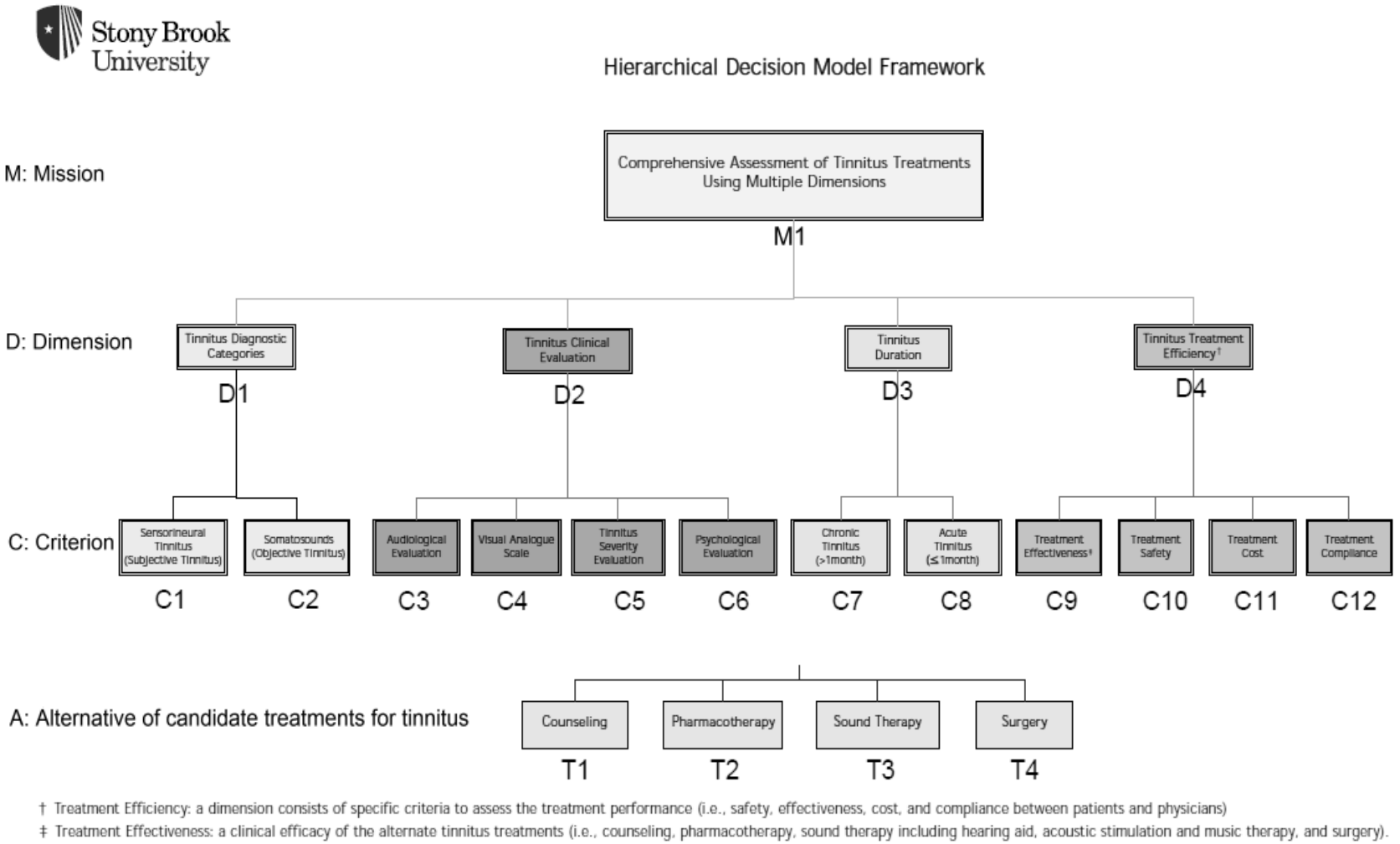


Figure 21: Verified Hierarchical Decision Model (v-HDM) for the Multi-dimensional TTA

4.3.4 Phase 4: Organizing the HDM Expert Panel

The process for organizing the expert panel is a requisite to compile the research instrument based on their value judgments. Snowballing and networking methods have been applied to institute an initial HDM expert panel. Snowballing is applicable to search for experts based on the publications in international journals in the literature review databases. Networking is used to identify and qualify the listed provisions of the expert panel. An initial expert panel is an essential foundation to organize a full expert panel for an HDM. The expert panel provides the feedback to verify and confirm the HDM decision elements: multiple dimensions, criteria and sub-criteria associated with each dimension. For the HDM validation, the peer review of a panel of experts may be applicable.

For tinnitus treatment assessment (TTA), the exclusive expert panel encompasses the otorhinolaryngologists with a specialty in tinnitus. Expert judgments by qualified decision makers are required to rank the multiple DCDE dimensions, criteria associated with each dimension and alternatives or decision options for comprehensive TTA. To qualify the expert panel for TTA, the specific requirements are illustrated in Table 8. The detailed organization process of an HDM expert panel is explained in the following section.

Table 8: Requirements of the HDM Expert Panel for TTA

Requirements	**Rating (High/Medium/Low)**
Otorhinolaryngologists with a Specialty in Tinnitus	High
Clinical Practices (or Experience) for Tinnitus	High
Accessibility to the Interview to Compile the Research Instrument	High
Specialized Tinnitus Treatments (Certificates for a Particular Tinnitus Treatment)	Medium
Research Interests for TTA	Medium-High
Degrees: Both MD and PhD	Low

4.3.5 Phase 5: Designing and Completing the HDM Research Instrument

The validated HDM research instrument denote the judgment quantification questionnaires, as illustrated in Appendix A. The expected outcomes to design and compile the research instrument are as follows:

(1) Overview and recommendation for building a TTA literature library to address the HDM framework and decision elements;

(2) Verification and validation (V&V) to approve the HDM framework and its decision elements: the mission, dimensions, criteria and sub-criteria or factors;

(3) Ratio-scale pair-wise comparisons (or value judgments of the expert panel) to rank the multi-level decision elements.

4.3.6 Phase 6: Analyzing the HDM Results

To acquire HDM treatment values (TV_n), the ranking values of each alternative tinnitus treatment will be analyzed with consideration of each dimension and criterion, as illustrated in Table 9.

Table 9: Analysis of the HDM Results

Analysis	**Outcome**
Quantification of expert judgments or ratio-scale pair-wise comparisons (RSPC) with respect to multiple DCDE dimensions	(1) Relative ranking values of each dimension (2) Level of inconsistency (LOI) for (1) (3) Level of disagreement (LOD) for (1)
Quantification or RSPC with respect to all-inclusive criteria	(4) Relative ranking values of each criterion (5) Level of inconsistency (LOI) for (4) (6) Level of disagreement (LOD) for (4)
Quantification or RSPC with respect to the alternative tinnitus treatments associated with each criterion	(7) Relative ranking values of each alternative with respect to each criterion associated with each dimension (8) Level of inconsistency (LOI) for (7) (9) Level of disagreement (LOD) for (7)
Calculations for treatment values (TV_{dn}) with respect to each dimension	Treatment values (TV_{dn}) of each dimension
Calculations for total treatment values (TV_n) associated with each alternative tinnitus treatment	Treatments values (TV_n)

If there are several unacceptable value judgments that exceed the guidelines of the levels of inconsistency (LOI) and disagreement (LOD), which is 0.1 out of 1.0, the research coordinator

will provide the analysis results to the experts simultaneously and reapply the relevant research instrument. The detailed analysis process for LOI and LOD is described in Section 4.5.

4.3.7 Phase 7: Compiling the HDM Gap Analysis (HDM-GA)

To comprehend the consistency in quantifying research instrument together with the synthesis of value judgments, this final phase fosters compiling the percentile scale comparisons with respect to alternatives between the initial treatment judgment values ($S1_n$) and the final calculated treatment values (TV_n). The HDM Gap Analysis (HDM-GA) denotes the mathematical deduction, as illustrated in Equation 1.

$$G_n = \frac{TV_n - S1_n}{S1_n} \times 100$$

where,

n the number of alternative tinnitus treatment in an HDM

$S1_n$ the initial judgment value of the n^{th} alternative

TV_n the final HDM Treatment Value (TV) of the n^{th} alternative

G_n the percentile gap value of the n^{th} alternative tinnitus treatment

Equation 1: Calculations for the HDM Gap Analysis

4.4 Organization of the HDM Expert Panel

4.4.1 Introduction of Expert Judgment

For tinnitus treatment assessment, the decision makers are otorhinolaryngologists with a specialty in tinnitus; the specialized ENT doctors are the experts in this study. The expert judgments determine the qualified responses to the research instrument. To elicit the expert judgments, the organization process and the expected outcomes are illustrated in Table 10.

Table 10: Organization Process and Expected Outcomes for Expert Judgment Quantification

Process	**Expected Outcomes**
Instituting the body of knowledge for the attributes of the research instrument	(1) Appropriate literature review
Qualifying the literature review	(2) Recommendations and advice to comprehend literature (3) Specific research questions and objectives (or the mission)
Developing HDM frameworks in categories of the literature review	(4) Decision elements: multiple dimensions, criteria and sub-criteria or factors (5) The initial HDM frameworks (i-HDM)
Developing the research instrument with the refined questionnaire to avoid ambiguity	(6) Research instrument proposal (7) Self-evaluation report (or feasibility studies) to validate time constraint and quality of questions
Presenting and motivating the experts to volunteer to work for the development of the HDM frameworks and research instrument	(8) The verified HDM framework (v-HDM) (9) Schedule or plan to coordinate the HDM framework and research instrument (or interview questions for the expert judgments)

Planning and preparing for the first expert judgments with initial expert panel	(10) Scenarios of the expert judgments (11) Finalized operating method: Verbal interview-based value judgments
Compiling the first research instrument and following-up (or networking)	(12) Data sets from the expert judgments with ratio-scale pair-wise comparisons (13) Research instrument analysis report with the relative ranking values (14) The levels of inconsistency and disagreement for each expert judgment
Verifying and validating the quantified data of expert judgments; coordinating to reapply the research instrument for the experts who exceed the required level of inconsistency (LOI).	(15) Validated results of expert judgments (16) Gap analysis report between initial judgment values without a decision model and final treatment values using the HDM (17) Plan for the future work and improvement activities

The research instrument denotes the quantification method of expert judgments using ratio-scale pair-wise comparisons (RSPC) with respect to multiple dimensions, criteria and alternatives. In particular, the interview-based expert judgments have been applied for tinnitus treatment assessment (TTA).

4.4.2 Acquisition of Experts for the Identification of the Panel

Two acquisition methods of snowballing and networking have been applied to organize the qualified HDM expert panel. The snowballing methodology is applied to broadly search the experts or authors based on their publications in international journals in the databases of literature review. The networking method is employed for the identification and qualification of the expert panel. In particular, to validate the expert panel for a tinnitus treatment assessment (TTA) decision model, there are the following criteria: (1) accessibility to the interview to compile expert value judgments; (2) compatibility with Korea's otorhinolaryngological society of tinnitus, that represents the expertise and research interest of tinnitus research or tinnitus treatment with a tinnitus specialty; and (3) the certificates or doctoral degrees, such as MD and PhD, to comprehend current tinnitus treatments. The general criteria present the clinical practices for tinnitus and experiences of specialized tinnitus treatments.

4.5 Disagreement Level Analysis of Expert Judgments

This research is designed to analyze the value judgments from multiple experts. With the application of the research instrument, the expert judgments are compiled and validated by the consensus-based decision-making process of the HDM. The extent of consensus denotes the disagreement level in the HDM. The gaps in expert profiles represent the bias of their judgment attributes: body of knowledge, specialized experience, current research activities, institutions, individual characteristics, workload, social and cultural backgrounds. To mitigate the risks of disagreement, introductory presentations with sufficient information and illustration are required. The iteration methodology to obtain expert judgments with a peer review is the consensus-based "Delphi technique" (Linstone, 1985). The Delphi technique is a well-established expert judgment methodology to obtain the consensus of a panel of experts (Deckers et al., 2015; Jander, Crutzen, Mercken, & De Vries, 2015; Keeney, Hasson, & Hugh,

2001; Lazić et al., 2014; Maertens, Aggarwal, Macdonald, Vermassen, & Van Herzeele, 2015; Zaragoza, Ferrer, Maseda, Llinares, & Rodriguez, 2014). In an HDM or pair-wise comparison matrix (PCM) decision analysis, the confidence level indicators denote two analytical elements: inconsistency and disagreement. In the PCM decision analysis, the validation of consistency is a critical step (Zhang, Sekhari, Ouzrout, & Bouras, 2014). Inconsistency is related to the individual expert responses to the interview-based survey questionnaire (or the judgment qualification instrument).

The guidelines of the levels of inconsistency and disagreement will be applied to validate the expert value judgments in the HDM. The level of inconsistency (LOI) pertains to a logical response to the research instrument with expert judgments. If the LOI is more than 0.10, the coordinator will provide the analysis results to the issued experts concurrently and reapply the relevant research instrument to aggregate the valid judgment values. Analyzing the level of disagreement (LOD) is a critical phase to validate the consensus among the experts rather than the consistency of a single expert. The LOD denotes the gaps in the aggregate of expert judgments. The LOD is the mean of inconsistency judgment values from multiple experts on the expert panel. At the same time, there is a criterion of LOD that is less than 0.10. The value of 0.10 of the LOD denotes a 90% agreement among multiple experts in the expert panel. To comprehend LOI and LOD in this research, a Pair-wise Comparison Matrices (PCM) software, developed by Portland State University, is applied.

The PCM software provides the analytical values of inconsistency and disagreement based on the responses of a panel of experts to the judgment quantification instrument. For instance, the expert judgments of the four DCDE dimensions satisfy the requirement of the level of inconsistency (LOI) and present the inconsistency values: 0.008 of Expert 1, 0.004 of Expert

2, and 0.005 of Expert 3 less than 0.10. The validated value of 0.053 meets the level of disagreement (LOD) criterion, being less than 0.10, as illustrated in Figure 22.

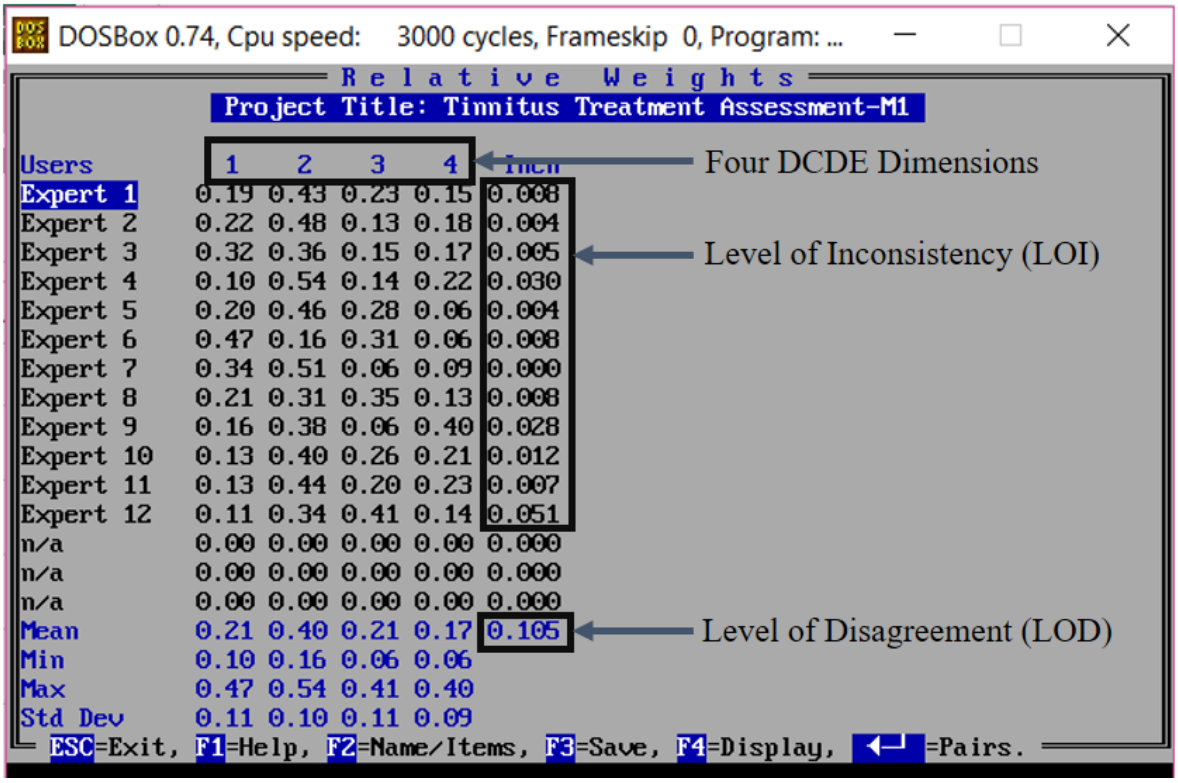


Figure 22: Example of the PCM Software to Analyze Expert Judgments

To comprehend the rationale of disagreement, the coordinator may investigate the distinctive attributes of each expert judgment. If the initial judgments are not available to satisfy the consensus-based appraisal (or LOD), the second round of the research instrument may be applicable. In the Delphi consensus technique, the reiterations are applied to avoid substantial disagreement. The detailed analysis for LOI and LOD is illustrated in Chapter 6.

4.6 Applied Hierarchical Decision Model for Tinnitus Treatment Values

The multi-level Hierarchical Decision Model (HDM) is designed to assess the tinnitus treatment values based on expert judgments. In particular, the initial HDM (i-HDM) framework for tinnitus treatment assessment (TTA) pertains to the five-level decision model that subsumes dimensions, criteria and sub-criteria, or factors under the mission of TTA, as illustrated in Figure 23.

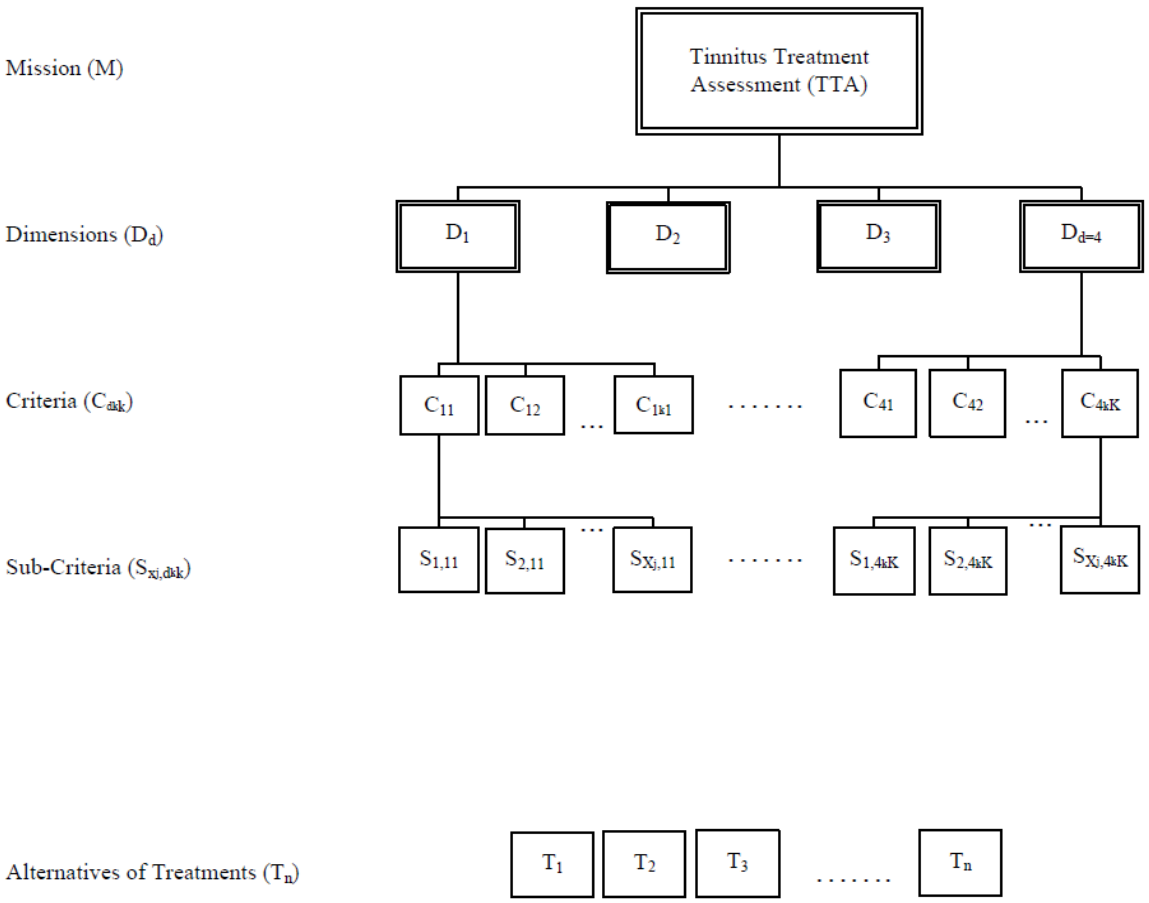


Figure 23: Hierarchical Decision Model for TTA with Sub-Criteria

To assimilate this TTA HDM model, Figure 23 illustrates a hierarchical structure. The decision element levels encompass: the mission; multiple dimensions; the criteria associated with each dimension; and the sub-criteria with respect to each criterion. The bottom level of the HDM subsumes the alternatives to treatments for multidimensional decision analysis in tinnitus treatment assessment. The decision elements at different appropriate levels with available measurements are ranked with respect to:

I. The top level (Level 1): the mission or the objective with initial judgment ($S1_n$), as shown in Equation 1;

II. The second level (Level 2): dimensions with ratio-scale pair-wise comparisons (RSPC) that range from 0.0 to 1.0, totaling a constant sum of 1.00 for that level using the expert judgment quantification instrument (EJQI);

III. The third level (Level 3): criteria with RSPC using EJQI;

IV. The fourth level (Level 4): sub-criteria with RSPC using EJQI or descriptive analysis to define each criterion;

V. The bottom level (Level 5): alternatives of treatments or treatment options with pair-wise comparisons associated with each criterion.

The ranking values are aggregated by expert judgments using ratio-scale pair-wise comparisons with the research instrument and the panel of experts. The relative fractional ranking values are converted to percentile values that range from 0% to 100%, which total a constant sum of 100%, as detailed in Chapter 6. For the synthesis of ranking values with respect to each level without the level of sub-criteria or factors, the expert panel compromises on the HDM decision elements, as illustrated in Figure 24. The treatment values will be calculated by Equations 2 and 3.

$$TV_{dn} = \sum_{d=1}^{D} . \sum_{k=1}^{C_d} (y_{dk})(Z_{dkn})$$

where,

n the number of alternatives in an HDM

D the number of dimensions with respect to the mission

C_d the number of criteria with respect to the dimension (d)

y_{dk} the relative importance of the k^{th} criterion with respect to the dimension (d)

Z_{dkn} the relative importance of the n^{th} alternative in the view of the dimension (d) with respect to the criterion (k)

TV_{dn} the treatment value (TV) of the n^{th} alternative with respect to the dimension (d)

Equation 2: Treatment Value (TV_{dn}) Calculations with Respect to the Dimension (d)

The ranking of these tinnitus treatment values (TV_{dn}) for each dimension addresses the attributes between the dimensions and the alternative treatments. TV also addresses which dimensions have positive and negative directionality with the alternative tinnitus treatments and gaps in TV with respect to each dimension. Furthermore, to comprehend the final treatment values, the TV_{dn} can be aggregated to a synthesis value for each tinnitus treatment by calculating the total Treatment Value (TV_n) to the HDM mission. This TV_n ameliorates the need to address which dimensions are most significant in that level.

$$TV_n = \sum_{d=1}^{D} (x_d)(TV_{dn})$$

where,

n the number of alternatives in an HDM

D the number of dimensions with respect to the mission (M)

x_d the relative importance of the d^{th} dimension with respect to the mission

TV_{dn} the treatment value (TV) of the n^{th} alternative with respect to the dimension (d)

TV_n the TV of the n^{th} alternative in the view of all dimensions with respect to M

Equation 3: Calculations for the Final Treatment Values (TV_n)

The TV_n is the treatment value of alternative tinnitus treatment (n) to consummate the mission that is the multidimensional tinnitus treatment assessment (TTA). The TV_n calculation includes the pair-wise comparison matrices to reckon the relative significance of dimensions and criteria. The treatment values range from 0 to 100, which total a constant sum of 100, as detailed in Chapter 6.

$$\sum_{d=1}^{D} x_d = 1$$

where,

$x_d > 0$

x_d the relative importance of the d^{th} dimension with respect to the mission

Equation 4: Constant Sum of Relative Importance for the Dimension (d)

Ratio-scale pair-wise comparisons are used to obtain the relative ranking values via the research instrument. The relative fractional ranking values range from 0 to 1.0, which total a constant sum of 1.0. For example, a ratio-scale of D1 and D2 is 3:7 from one expert (X_1= 0.3; X2 = 0.7). The aggregate values of x_d and y_{dk}, as illustrated in Equations 4 and 5, for the relative importance of the four dimensions and the twelve criteria are computed as the mean of the individual expert values. For example, there are x_1 = 0.24, x_2 = 0.42, x_3 = 0.17 and x_4 = 0.17 with $x_1 + x_2 + x_3 + x_4 = 1.0$, as illustrated in Figure 24.

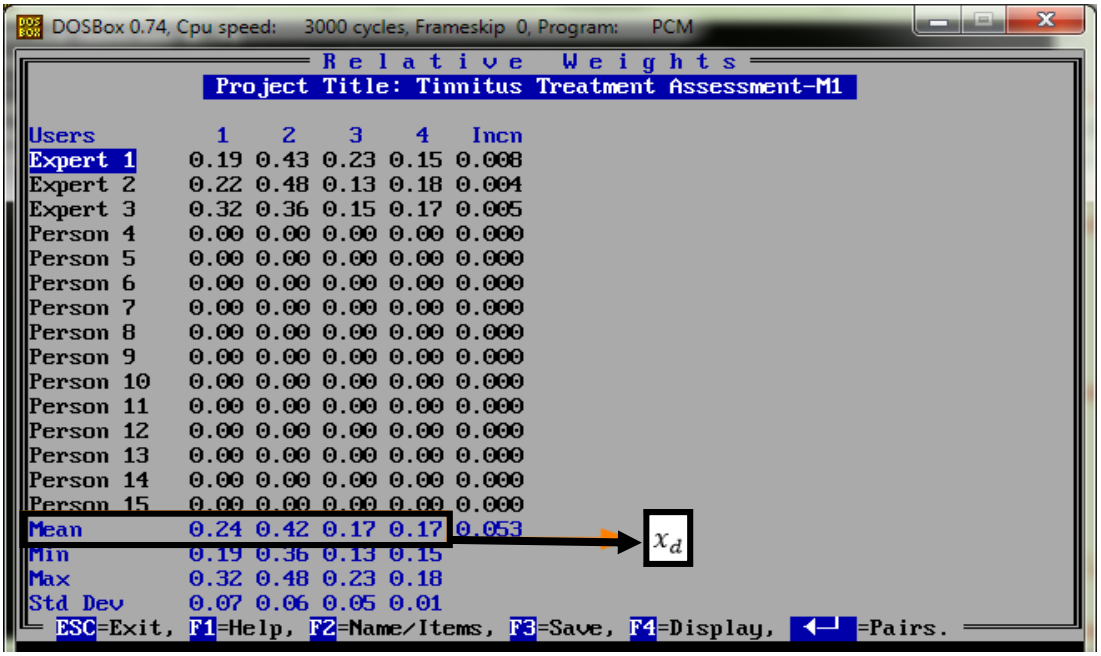


Figure 24: Example of the Values of the Relative Importance with Respect to the Four DCDE Dimensions

$$\sum_{d=1}^{D}\sum_{k=1}^{K} y_{dk} = 1$$

where,

$y_{dk} > 0$

y_{dk} the relative importance of the k^{th} criterion with respect to the dimension (d)

Equation 5: Constant Sum of Relative Importance for the Criterion (k)

To diminish the complexity of the HDM, the level of sub-criteria or factors can be eliminated, as illustrated in Figure 25.

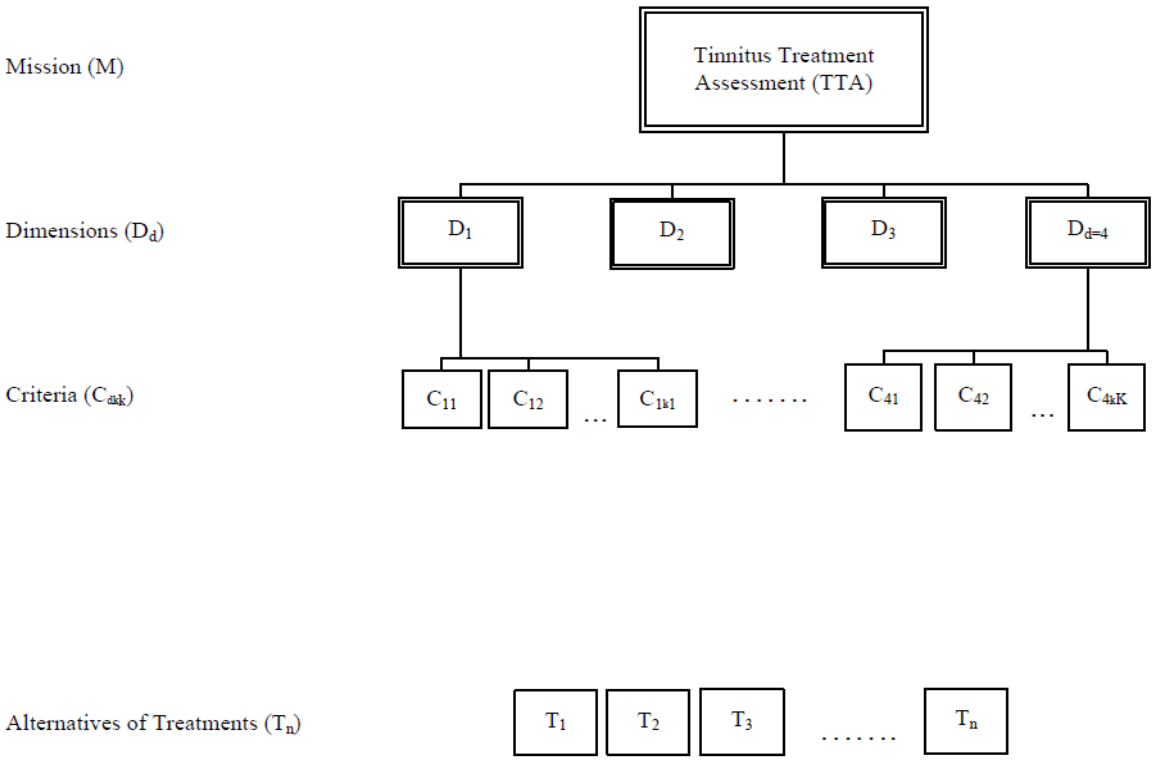


Figure 25: Hierarchical Decision Model for TTA without Sub-Criteria

4.7 Data Collection

4.7.1 Research Instrument Process

In the HDM, the data collection phase indicates the process to develop and compile the research instrument, as illustrated in Figure 26.

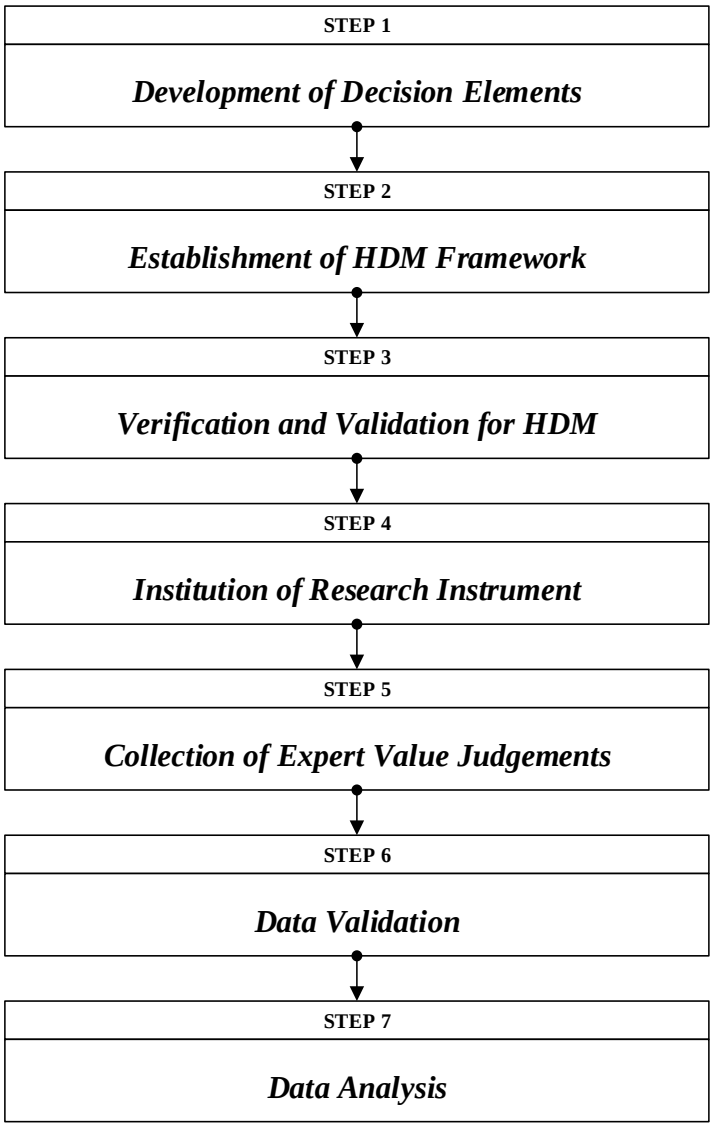


Figure 26: Research Instrument Process

The above research instrument process includes the HDM development with verification and validation. The HDM is applied to implement the research instrument with the attributes of research objectives, research questions, and decision elements. The responses to the research

instrument are compiled for data acquisition. The collected value judgments of the panel of experts are validated and analyzed to fulfill the research objectives (or the mission).

4.7.2 Data Validation

Satisfying the data validity is a significant step in collecting the most appropriate data.

To validate the aggregated data based on expert value judgments, the criteria of the levels of inconsistency and disagreement will be applied. The PCM software is used to compute the specific values of inconsistency and disagreement for competent data validation. The data analysis and validation process are detailed in Chapter 7.

Chapter 5

Contribution to the Body of Knowledge

To assess how much this research could benefit the decision makers of tinnitus management (TM) and stakeholders of domestic or international otorhinolaryngological societies of tinnitus for tinnitus treatment assessment (TTA), the literature review presents the status of tinnitus, the complex TM, global tinnitus prevalence, an insufficient cure for tinnitus, lack of decision analysis for TTA and the social risk of reduced quality of life (QOL) due to severe tinnitus. Since this dissertation research is free from financial obligations, the research objective can better focus on the positive intellectual benefits for all-inclusive stakeholders. The author believes this multidimensional TTA using the multi-criteria decision analysis should be an ameliorative effort for individual decision makers in the societies of otorhinolaryngologists, adjunct researchers and associated institutions for TM, as comprehensively distributed, as it is useful to better understand the all-inclusive TTA.

In 2009, a multidisciplinary tinnitus treatment study launched as a team research project including an otorhinolaryngologist, a director of General Electronics (GE), a government banker and the author of this dissertation as a facilitator or a study coordinator in the MBA program at Korea University Business School (KUBS). The increasing research interests have been aggregated by the suffering voices of senior tinnitus patients around the author's family and community, including a senior pastor Hyun Jun Kim in Dong-An Korean Presbyterian Church. The comprehensive assessment of tinnitus treatments can be achieved through the verified HDM (v-HDM) in multi-criteria decision analysis (MCDA) methodologies based on

expert judgment quantification with twelve ENT doctors specialized in tinnitus management (TM).

To obtain expert judgments, this HDM-based dissertation research applies to the “Delphi technique” (Linstone, 1985). The Delphi technique is explained in Section 4.5. The research methodology of the HDM, namely a Mission-Objectives-Goals-Strategies-Actions model (MOGSA model) has been developed by Dr. Kocaoglu and researchers at Portland State University (PSU), as detailed in Section 2.6. This research is the first HDM case study to comprehend the multidimensional tinnitus treatment assessment using the multi-criteria decision analysis (MCDA) and the consensus-based Delphi technique through a PCM.

Chapter 6

Decision Modeling

In the literature review, the gap analysis presents the research trend with respect to multiple Diagnostic-Clinical-Duration-Efficiency (DCDE) dimensions represented in Figure 27. The mitigation of the biased existing research associated with the multiple DCDE dimensions is aimed at ascertaining the gaps in tinnitus treatment assessment (TTA) and ameliorating the all-inclusive TTA. In particular, the dimension of clinical evaluation (D2) has a substantial role in TTA when compared to the other three dimensions. One and two dimensional TTAs (1D and 2D-TTAs) have a greater portion than 3D and 4D-TTAs in D2. Furthermore, the 4D-TTAs pertain to a descriptive evaluation without multiple criteria associated with each dimension and the decision analysis model.

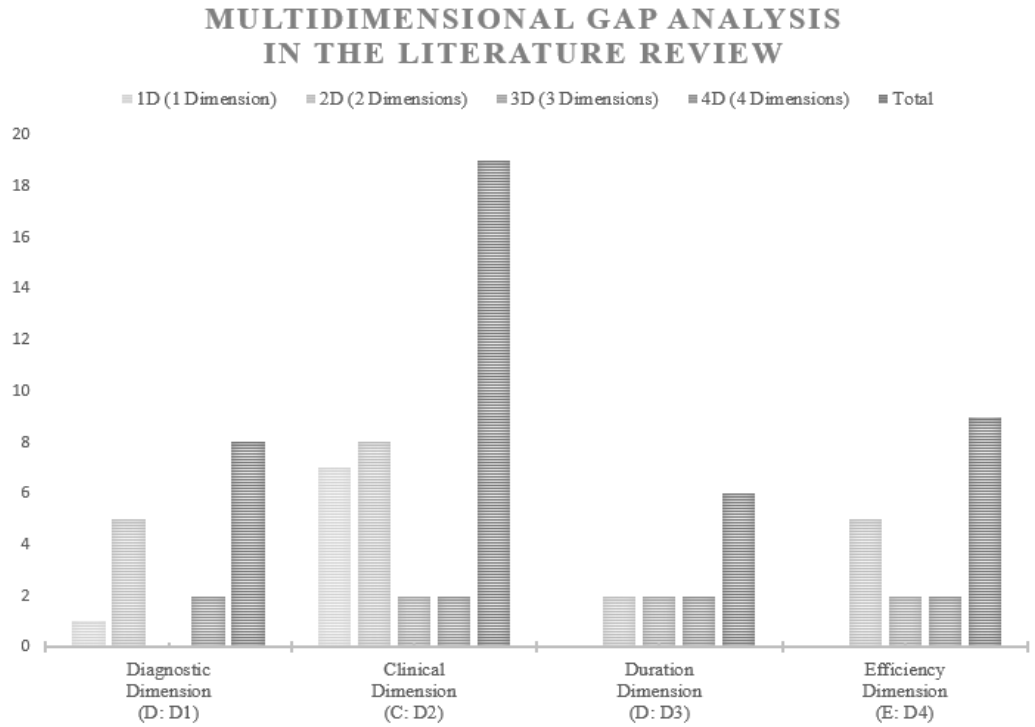


Figure 27: Multidimensional Gap Analysis

To address multi-level decision elements: the mission (Level 1), multiple dimensions (Level 2), multifaceted criteria (Level 3) associated with each dimension and candidate alternatives (Level 4), the literature review is a requisite.

6.1 Decision Modeling with Multiple Dimensions, Criteria and Alternatives

This literature review recapitulates the wide range of criteria and sub-criteria or factors to compile a hierarchical decision-model (HDM) framework for tinnitus treatment assessment (TTA). The multi-dimensional TTA is applied to attain the most outstanding alternative treatment associated with 12 criteria. With respect to the four DCDE dimensions, the twelve decisive criteria are illustrated in Table 11. An HDM criterion may consist of sub-criteria or factors. In the HDM for TTA, the factors help to define the associated criterion. The factors are illustrated in Appendix B. To address the top rank treatment, the alternatives (or candidate tinnitus treatments) include: (1) T1: counseling, (2) T2: pharmacotherapy, (3) T3: sound therapy and (4) T4: surgery.

Table 11: Criteria Associated with each Dimension

D1: Diagnostic	D2: Clinical	D3: Duration	D4: Efficiency
C11: Sensorineural Tinnitus (Subjective Tinnitus)	C21: Audiological Evaluation	C31: Chronic Tinnitus (>1month)	C41: Treatment Effectiveness
C12: Somatosounds (Objective Tinnitus)	C22: Visual Analogue Scale	C32: Acute Tinnitus (≤1month)	C42: Treatment Safety
	C23: Tinnitus Severity Evaluation		C43: Treatment Cost
	C24: Psychological Evaluation		C44: Treatment Compliance

6.2 Diagnostic Dimension

D1: Tinnitus Diagnostic Categories

Tinnitus is a prevalent health condition experienced by approximately 10% to 15% of the US population, but this common disorder significantly undermines the quality of life (QOL) of about 1% to 2% of all citizens (Langguth et al., 2013). The causes of tinnitus are multifarious diseases and its etiology is unclear (Kishikawa, Tsunoda, Tanaka, & Kishimoto, 2014). The diagnostic dimension, which is the first dimension (D1), includes two tinnitus diagnostic categories: somatosounds as an objective tinnitus, and sensorineural tinnitus as a subjective tinnitus.

Sensorineural tinnitus is the main subject of tinnitus diagnostics in severely distressed patients with chronic otitis media, and its diagnostics pose a number of arduous problems to assess tinnitus treatments. Objective tinnitus of pulsatile tinnitus is also discernable during the diagnosis of tinnitus (Kim et al., 2011).

Rustling tinnitus, which is an initial symptom of a nasopharyngeal lesion, is a sporadic case of tinnitus for the explicit diagnosis of unrevealed auditory disorders (Kishikawa et al., 2014). When contemplating the functional variances of different manifestations of tinnitus, clinicians demand both enrichment and aggrandizement of tinnitus diagnostic research (Adjamian, Hall, Palmer, Allan, & Langers, 2014).

Furthermore, the limited accessibility of clinicians' expertise, regional disparity of diagnostic resources and divergent patients with varying degrees of compliance, stimulate otorhinolaryngologists to establish the standard of diagnosis for tinnitus treatment (Baguley et al., 2013).

6.2.1 Sensorineural Tinnitus Criterion

C11: Sensorineural Tinnitus (Subjective Tinnitus)

Sensorineural tinnitus can transpire from cochlear lesions such as acute and temporary hearing loss, degenerative hearing loss, noise trauma, and ototoxic drugs. For example, hearing loss can cause irregular sensory function and be perceived as subjective tinnitus, but hearing loss is correlated strongly with tinnitus. One reason is the fact that there is evidence to suggest that hearing loss is not a direct contributor in the development of tinnitus. The relevance of subjective tinnitus to hearing impairment is as follows: imaginary noise caused by limb loss, joint disorders, bodily injuries that have been accompanied by the generation and tenacity of tinnitus (Langguth et al., 2013). Subjective tinnitus can be associated with psychological symptoms such as emotional distress, disorder and psychological stress, or hypersensitivity to noise or symbolic sound.

Subjective tinnitus is the foremost otoneurological disorder with no profound treatment (Bertet et al., 2013). For the management of subjective tinnitus, the accuracy of diagnosis is a requisite. Korea's otorhinolaryngologists consider subjective tinnitus to attain evidence-based treatments according to the appropriate pathological categorization (Yoo et al., 2013).The severity of subjective tinnitus, which is perceived only by patients, engenders a considerable amount of debate regarding treatment selection (Belli et al., 2008).

6.2.2 Somatosounds Criterion

C12: Somatosounds (Objective Tinnitus)

Somatosounds, or objective tinnitus, is generated within the body associated with vital organs such as blood vessels, muscle, and the patulous Eustachian tube. The conception (cognitive sound) of objective tinnitus is audible noise, which can be a source without triggers from

external acoustic stimulus such as external auditory noise. The sound created by objective tinnitus is not limited to the patient. Somatosounds are detectable, and there are etiologies to assist an examiner in measuring and monitoring objective tinnitus with the auditory perception generated by myoclonic disorder, abnormal blood vessels, and defects of the inner ear (Langguth et al., 2013; Kang, Park, Kwon, & Kim, 2011).

Objective tinnitus is more distinctive than subjective tinnitus. Objective tinnitus is diagnosed by measurements of bodily sounds, whereas subjective tinnitus is caused by multifarious disorders including neurological functions without a source of audible noise (Belli et al., 2008). A pulsatile tinnitus is classified as objective tinnitus, and accounts for approximately 4% of this objective tinnitus cases. Surgical treatment is effective for pulsatile tinnitus (Kang et al., 2011). Cochlear implantation is one of the surgical operations used to relieve tinnitus in Korea. Cochlear implantation (CI) can reduce the tinnitus handicap inventory (THI) scores effectively compared to THI scores and visual analogue scale (VAS) scores obtained before the operation. This improvement shows the advantageous effect of cochlear implantation (CI), and CI apparently has been considered as a guide to decrease tinnitus in patients with profound sensorineural hearing loss (SNHL), as illustrated in Figure 28 (Kim et al., 2013).

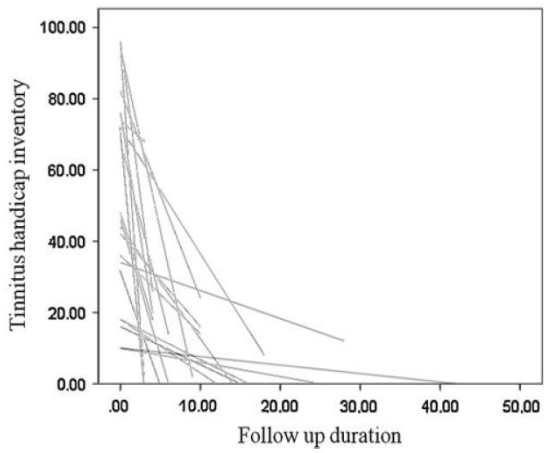


Figure 28: Tinnitus Relief and the Reduction of the Tinnitus Handicap Inventory (THI) Scores after Cochlear Implantation (CI) (Kim et al., 2013)

6.3 Clinical Evaluation Dimension

D2: Tinnitus Clinical Evaluation

In particular, tinnitus clinical evaluation is the main process to institute the treatment scheme for the classification of tinnitus, measurement of its severity, and the consideration of treatment efficiency. Audiological evaluation is fundamental to identify the category of tinnitus and the levels of severity for the decision of effective tinnitus treatments.

For instance, clinical reviews of the effectiveness of counseling for a tolerable degree of tinnitus, tinnitus retraining therapy (TRT) for objective and vascular tinnitus, counseling with pharmacotherapy for myoclonic tinnitus, are absolutely imperative in medicine (Bae et al., 2014). The clinical evaluation dimension is an important complement to integrate tinnitus clinical examinations such as audiological evaluation, visual analogue scale, tinnitus severity evaluation, and psychological evaluation.

Audiological evaluation is useful to develop an applicable sound simulation and understand that sensorineural tinnitus can decrease through clinical hearing recovery. Improved auditory levels can increase the sound level of ambient noise and lessen the difference between tinnitus and silence by hearing loss (Kim et al., 2011). Studies have shown that a psychological evaluation of tinnitus is helpful for a better understanding of psychiatric disorders or diseases with respect to the impact of tinnitus on quality of life (QOL).

For example, some of these psychiatric disorders can be depression, insomnia, anxiety and hyperacusis (Langguth et al., 2013). The hyperactivity disorder of auditory pathways, remapping of neural network structure, and pathophysiological alteration of sensory information are the causes of tinnitus in the system of auditory nerves.

6.3.1 Audiological Evaluation Criterion

C21: Audiological Evaluation

To evaluate the patients' hearing curve, audiological evaluation is the most important method. An interval of one second of silence is applied to measure the hearing sounds, being the iterative sounds with +3 dB phases and random selections of stimulated ear and frequency. The frequency distribution follows the international organization for standardization (ISO) 389-1 and ISO 389-5 with the hearing threshold: 125 Hz to 16 kHz. in ISO 389–5 (Bertet et al., 2013). The audiological evaluation includes the factors of audiometry, speech audiometry, minimum masking level, tinnitus matching and tympanometry.

6.3.2 Visual Analogue Scale Criterion

C22: Visual Analogue Scale

The visual analogue scale (VAS) is the evaluation report for measuring the patients' psychometric features: subject perception of tinnitus loudness (VAS loudness) and annoyance (VAS annoyance). To analyze the severity of tinnitus, both VAS loudness and VAS annoyance are applicable for chronic tinnitus (Adamchic & Langguth, 2012).

In the matching level, VAS ranges from 0 = completely different to 100 = identical, with the comparisons between existing tinnitus and tinnitus avatar (Bertet et al., 2013). The validated tinnitus questionnaires are applied to address the patients' tinnitus with the measuring of VAS loudness, VAS annoyance, VAS effect on life and VAS awareness with respect to tinnitus. A tinnitus handicap inventory (THI) is also applicable to identify tinnitus (Kim et al., 2013). For instance, there are visual analogue scale (VAS) scores for loudness, annoyance, effect on life, and awareness, as illustrated in Table 12.

Table 12: Example of Visual Analogue Scale (VAS) Scores (Kim et al., 2013).

	Preoperative mean ± SD	Postoperative mean ± SD	*p* value
Duration of tinnitus before CI (years)	13.6 ± 13.7		
Site of tinnitus (right:left:bilateral)	5:5:12		
Number of tinnitus (range)	2.5 ± 1.6 (1–6)		
Awareness (%)	48.4 ± 38.5	8.3 ± 11.3	<0.001*
VAS for loudness	5.4 ± 2.8	1.4 ± 2.0	<0.001*
VAS for annoyance	5.8 ± 3.2	1.3 ± 2.1	<0.001*
VAS for effect on life	6.0 ± 3.3	1.1 ± 2.0	<0.001*
THI	50.5 ± 28.7	10.1 ± 15.8	<0.001*

CI cochlear implantation, *VAS* visual analogue scale, *THI* tinnitus handicap inventory

Mann–Whitney test, * $p < 0.05$

6.3.3 Tinnitus Severity Evaluation Criterion

C23: Tinnitus Severity Evaluation

Substantial stressed tinnitus denotes “severe” or “annoying” tinnitus. This severe tinnitus affects the patient’s quality of life (QOL) (Elgoyhen & Langguth, 2011). The individual evaluation of tinnitus severity is commonly distinctive among patients. Tinnitus treatment evaluation is restricted to the quantification of tinnitus disability (Belli et al., 2008). To identify the attributes that determine the severity of tinnitus, handicaps, the Tinnitus Handicap Inventory (THI), Tinnitus Reaction Questionnaire (TRQ), Tinnitus Handicap Questionnaire (THQ) and Tinnitus Functional Index (TFI) have been developed. THI, TRQ, THQ and TFI have been applied in clinical approaches for tinnitus treatment assessment.

Complex psychological problems are related to tinnitus and these severity instruments address the emotional reaction of tinnitus patients, including insomnia (Tunkel et al., 2014a). In the UK, for tinnitus treatment assessment, the Tinnitus Handicap Inventory (THI) and the Tinnitus Handicap Questionnaire (THQ) have been applied (Hoare et al., 2011). In the Republic of

Korea (ROK), THI scores and Spearman correlation analysis are applicable to evaluate the severity of tinnitus, as illustrated in table 13.

Table 13: Example of Spearman Correlation Analysis (Kim et al., 2013)

	Preoperative factors									Postoperative factors		
	Age at surgery	Duration of HA	HL of operated ear	HL of non-operated ear	VAS of LD	VAS of AN	VAS of EFF	VAS of AW	THI	HL in sound field	SDS	FU
Correlation coefficient	0.357	0.081	0.014	0.228	0.661	0.631	0.491	0.449	0.790	0.048	−0.458	−0.286
p value	0.103	0.727	0.951	0.308	0.001*	0.002*	0.020*	0.036*	<0.001*	0.834	0.100	0.198

HA hearing aid, *HL* hearing level (average air-conduction threshold at 0.5, 1, 2, 4 kHz), *VAS* visual analogue scale, *LD* loudness, *AN* annoyance, *EFF* effect on life, *AW* awareness, *THI* tinnitus handicap inventory, *SDS* speech discrimination score, *FU* follow-up duration

* $p < 0.05$

6.3.4 Psychological Evaluation Criterion

C24: Psychological Evaluation

In the UK, for psychological tinnitus assessment, the Department of Health (DOH) guidelines apply the Beck Depression Inventory (BDI), the Beck Anxiety Inventory (BAI) and the Hospital Anxiety and Depression Scale (HADS). These instruments are circumscribed by the clinical applications to evaluate the psychological effects of tinnitus (Hoare et al., 2011). To ascertain the patients' psychiatric comorbidities caused by tinnitus, anxiety and physical disorders are evaluated.

The tinnitus-related psychiatric symptoms present a convoluted chronic condition and engender debate to engage the professional clinicians. Chronic tinnitus may affect the severity of psychological disorders or factors such as depression and anxiety. An investigation of the psychopathological evaluation is necessary to prove the existence of severe tinnitus (Belli et al., 2008). It is worth reminding that the main factors of psychological evaluation are mental stress, tinnitus depression, emotional disorders and hyperacusis.

6.4 Duration Dimension

D3: Tinnitus Duration

The dimension that classifies the period of tinnitus treatment is considerable enough to establish a strategy for tinnitus treatment (TM). The appropriate tinnitus treatment approaches depend on the classification of different tinnitus features. In particular, clinicians treat chronic tinnitus differently according to the pathophysiological onset of the disorder. In this regard, the approaches to tinnitus treatment may diverge with the duration of the treated disorder. The treatment approaches to acute tinnitus are generally applicable with respect to sudden hearing loss, traumatic noise exposure, and treatment management accompanied by functional auditory recovery.

The boundary between acute tinnitus and chronic tinnitus is ambiguous to some extent between a period of 3-6 months and several years (Baracca et al., 2007). Studies have shown that counseling and sound therapy have been used to treat chronic subjective tinnitus (Adamchic & Langguth, 2012). For the identification of practical tinnitus treatments, Korea's otorhinolaryngologists have collected data for tinnitus duration that includes acute tinnitus as the treated disorder for less than one month and chronic tinnitus as the managed disease for more than a month (Yoo et al., 2013).

6.4.1 Chronic Tinnitus Criterion

C31: Chronic Tinnitus

In the ROK, the persistence of tinnitus symptom for over one-month (>1 month) denotes chronic tinnitus. In pharmacological approaches, chronic tinnitus pertains to the long-term management of antidepressants. Comorbid depression has been observed with chronic tinnitus. This pharmacotherapy is not a direct cure for tinnitus. In clinical practice for chronic tinnitus,

the treatment of tinnitus may be considered together with the cure for psychological disorders, such as depression and insomnia. For chronic tinnitus, consistent 6-month treatments have been applied for tinnitus relief (Elgoyhen & Langguth, 2011).

6.4.2 Acute Tinnitus Criterion

C32: Acute Tinnitus

Symptoms of tinnitus lasting less than a month (≤ 1 month) and specialized tinnitus associated with sudden hearing loss are known as acute tinnitus (Elgoyhen & Langguth, 2011; Yoo et al., 2013). The comorbid disorders with acute tinnitus are dizziness and hearing loss. The severity of acute tinnitus with hearing loss ranges from moderate to significant. The proportion of a spontaneous cure of acute tinnitus with abrupt hearing loss is high, at 65% (Elgoyhen & Langguth, 2011), but there is no accurate etiology in most acute tinnitus cases.

The period of complete recovery is commonly 2 weeks for acute tinnitus with hearing loss. For comorbid hearing loss rather than unilateral acute tinnitus, there are several treatments: (1) pharmacotherapy: intra-tympanic steroids, vasodilators and antiviral drugs and (2) Hyperbaric Oxygen Therapy (HBOT) which is an oxygen-boosting method. Acute tinnitus is related to noise-induced sudden hearing loss because of abrupt noise exposure events: industrial machines, gun shots, explosions, extremely high-volume (≥ the noise level of 85 dBA) sound generators, such as automobile horns and heavy metal music or rock concerts.

In developed countries, there is a prevalence of leisure noises. In particular, children, who are addicted to excessive amusement noises, have a higher potential risk for acute tinnitus and hearing loss. To assess acute tinnitus treatments, the compelling extension of clinical practices is imperative.

6.5 Efficiency Dimension

D4: Tinnitus Treatment Efficiency

Treatment efficiency is a mutual dimension that consists of specific criteria to assess the treatment performance with respect to treatment safety, treatment effectiveness, treatment cost, and treatment compliance between patients and physicians. For instance, the National Health Insurance Corporation (NHIC) has been the sole operating system integrated with the health insurance systems in the Republic of Korea (ROK) since 2000, and most citizens use the NHIC health insurance program in the ROK. The NHIC needs to consider a comprehensive evaluation to improve the efficiency of its health care program (H. Kim, Kwon, Yoon, & Hyun, 2013). In Korea, the NHIC has great influence on the decisions made by all participants in medicine with regard to administrative payment, effectiveness, safety and compliance.

Furthermore, the subsidies of two prescription drugs registered for tinnitus treatment have been reduced: ginkgo biloba was classified as an adjuvant in 2010; trimetazidine is now being debated for limited use due to its adverse effect of dyskinesia. Consequently, there will be no drugs covered by the NHIC for a pharmacotherapy of tinnitus. However, 93.3% of Korea's otorhinolaryngologists administer drugs as a first-order tinnitus treatment, but the evaluation score of effectiveness of tinnitus pharmacotherapy is below average (Yoo et al., 2013).

Despite the increasing need for the efficiency dimension in tinnitus treatments, studies indicate an insufficient capability for treatment assessment that can provide well-established evidence of effective medications. The efficiency dimension may be contextualized by the health care factors: effectiveness, safety, cost and compliance among clinicians, patients, government institutions, health care insurance stakeholders and multifarious decision makers for tinnitus management (TM) and tinnitus treatment assessment (TTA).

6.5.1 Treatment Effectiveness Criterion

C41: Treatment Effectiveness

The effectiveness of tinnitus treatment is the key performance criterion to evaluate the candidate treatments with respect to the dimension of tinnitus treatment efficiency. This effectiveness of treatment indicates the context of the desired efficacy and the curative outcomes from the alternative tinnitus treatments: counseling, pharmacotherapy, sound therapy, including acoustic stimulation, music therapy and other therapies related to hearing aids and surgery.

The effectiveness of candidate tinnitus treatments is evaluated by a panel of experts. For instance, a Korean clinical evaluation report reveals that tinnitus retraining therapy (TRT) and hearing aids are eminently effective, when the visual analogue scale (VAS) ranges from 6.6 to 7.0 (Yoo et al., 2013).

In the ROK, tinnitus pharmacotherapy using ginkgo biloba and benzodiazepines has become a frequent clinical practice for tinnitus, but this pharmacotherapy engenders considerable debates regarding its clinical effectiveness. Intra-tympanic steroid injection has two contrastive results: (1) the effective treatment for acute tinnitus and (2) the ineffective treatment for chronic tinnitus without hearing loss. Patient satisfaction measurement can be supplementary to evaluate the effectiveness of tinnitus treatment.

6.5.2 Treatment Safety Criterion

C42: Treatment Safety

With regard to the clinical practices of tinnitus treatments, the low induced adverse reactions, the avoidance of side effects, the low potential harm or injury, are subsumed under the criterion

of treatment safety. For instance, counselling and sound therapy are classified into safe treatments for tinnitus according to the VAS scores (Yoo et al., 2013). For the welfare of the individual patients and societies, the all-inclusive decision makers normally consider the safety of treatment as a fundamental clinical criterion.

6.5.3 Treatment Cost Criterion

C43: Treatment Cost

This criterion of treatment cost consists of two main factors: insurance payment and patient co-payment. For instance, the National Health Insurance (NHI) is an almost-exclusive health insurance system in the Republic of Korea. Since 1963, the NHI program (NHIP) has been implemented by the Medical Insurance Act for all Korea's citizens' healthcare. Since 1977, the NHIP has been regulated gradually by the extension of mandatory participation from medium to large-sized companies with more than 500 employees to all public offices and small to medium-sized enterprises (SMEs). Since 1989, almost all of Korea's citizens have enrolled in this compulsory NHI program. In contrast, Korea's private health insurance (PHI) is the second supplementary form of insurance to compensate for the residual NHI coverage (Choi et al., 2015).

In the ROK, the increase of copayments has resulted in the decrease in health care utilization and NHI policy makers consider the wide range of copayment schemes with the evaluation of the severity of diseases. Korea's otorhinolaryngologists provide the expert opinions to these NHI policy makers for the advanced employment of tinnitus treatment. Medical experts for tinnitus are substantial decision makers in the implementation of tinnitus treatments accompanied by the NHIP.

6.5.4 Treatment Compliance Criterion

C44: Treatment Compliance

Treatment compliance is the process of fulfilling the systematic treatment instructions or the consistency and fidelity to the physician's treatment as complied with by tinnitus patients. For instance, simple pharmacotherapy may encourage better compliance for tinnitus patients. To follow up on the patients who suspend their specific therapy, alternative tinnitus treatments are considered based on the assessment of the criterion of treatment compliance (Forti, Ambrosetti, Crocetti, & Del Bo, 2010). Someone follows the regimen prescribed by a physician or another health professional to treat subjective and chronic tinnitus. Otorhinolaryngologists need to maintain or improve the tinnitus treatment compliance to encourage patients to follow up with the clinical regimen (Canis, Olzowy, Welz, Suckfüll, & Stelter, 2011).

Chapter 7

Research Results

In Korea's case study for TTA, an HDM panel of experts consists of twelve otorhinolaryngologists with a specialty in tinnitus treatment. This dissertation research panel of twelve experts is classified as the expert population rather than the statistical sample in the ROK's otorhinolaryngological society for tinnitus.

The research instrument and decision elements — the four DCDE dimensions and associated criteria and factors or sub-criteria — are developed and validated to obtain the expert value judgments for the comprehensive assessment of tinnitus treatment, as shown in Appendices A and B.

The expert judgments are also validated by the level of inconsistency (LOI) and the level of disagreement (LOD), as described in Chapter 4. The computation software of pair-wise comparison metrics (PCM) is used for the collected data analysis and validation, as detailed in section 7.3. A PCM software is an MCDA tool developed by Department of Engineering Technology Management (ETM) at Portland State University (PSU).

7.1 Established Hierarchical Decision Model

Based on the iterative building and verifying of the initial HDM (i-HDM) frameworks to address the multiple dimensions and criteria with sub-criteria or factors detailed in Chapter 4, the intermediate HDM framework has been developed to select the final decision elements and institute the research instrument illustrated in Figure 29. The factors may be subsumed under

an HDM criterion. For instance, the eighteen factors are subsumed under the four criteria with respect to the clinical evaluation dimension (D2), as illustrated in Table 14.

Table 14: Factors with Respect to each Criterion in the Clinical Evaluation Dimension

Clinical Dimension	Audiological Evaluation Criterion	Visual Analogue Scale Criterion	Tinnitus Severity Evaluation Criterion	Psychological Evaluation Criterion
Factor 1	Audiometry & Speech Audiometry	VAS-Loudness	Tinnitus Handicap Inventory	Mental Stress
Factor 2	Minimum Masking Level	VAS-Annoyance	Tinnitus Handicap Questionnaire	Tinnitus Depression
Factor 3	Tinnitus Matching	VAS-Effect on life	Tinnitus Reaction Questionnaire	Emotional Disorder
Factor 4	Tympanometry	VAS-Awareness	Tinnitus Functional Index	Hyperacusis
Factor 5		VAS-Pitch		
Factor 6		VAS-Duration		

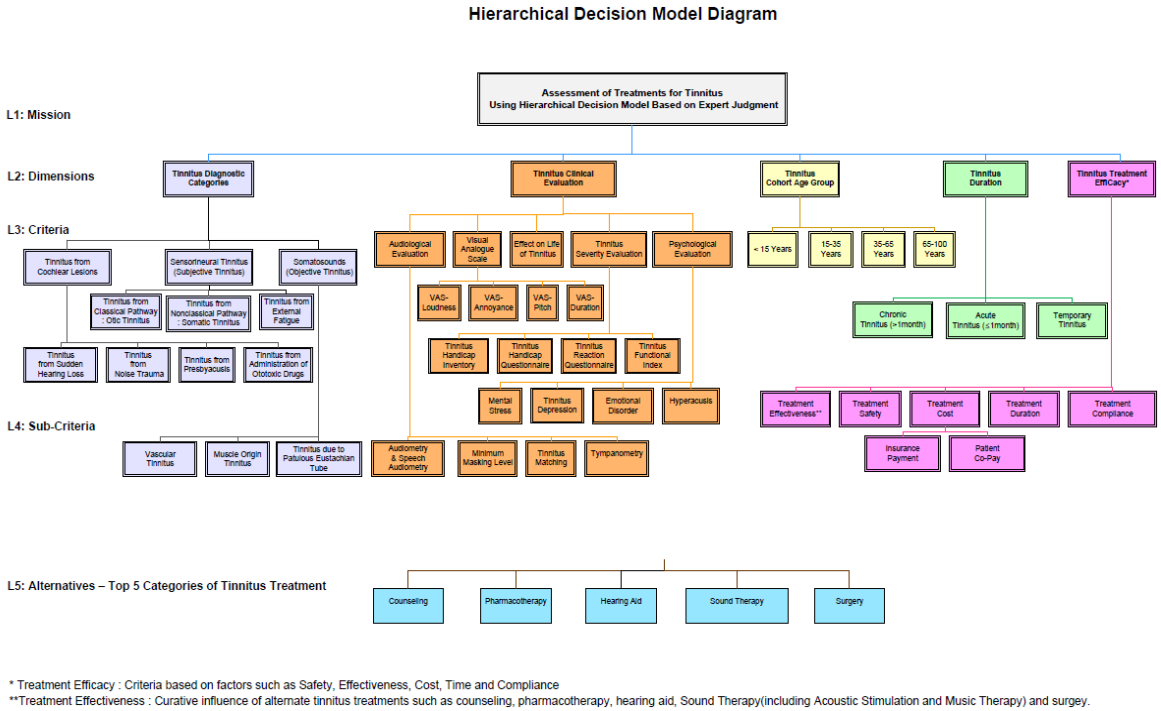


Figure 29: Intermediate HDM with the Twenty Criteria and Sub-Criteria (or Factors)

To attain the consensus-based HDM, the verification and validation of the initial and intermediate HDM frameworks are iterated by the panel of experts. In the final HDM, the wide

range of factors is eliminated. In particular, the factors (or sub-criteria) are used to define each criterion, as detailed in Chapter 6. The experts' feedback on an HDM criterion engenders the appropriate revisions. For example, the criterion of temporary tinnitus was replaced by the criterion of acute tinnitus. The final HDM has confirmed the twelve criteria without sub-criteria or factors, as illustrated in Figure 30.

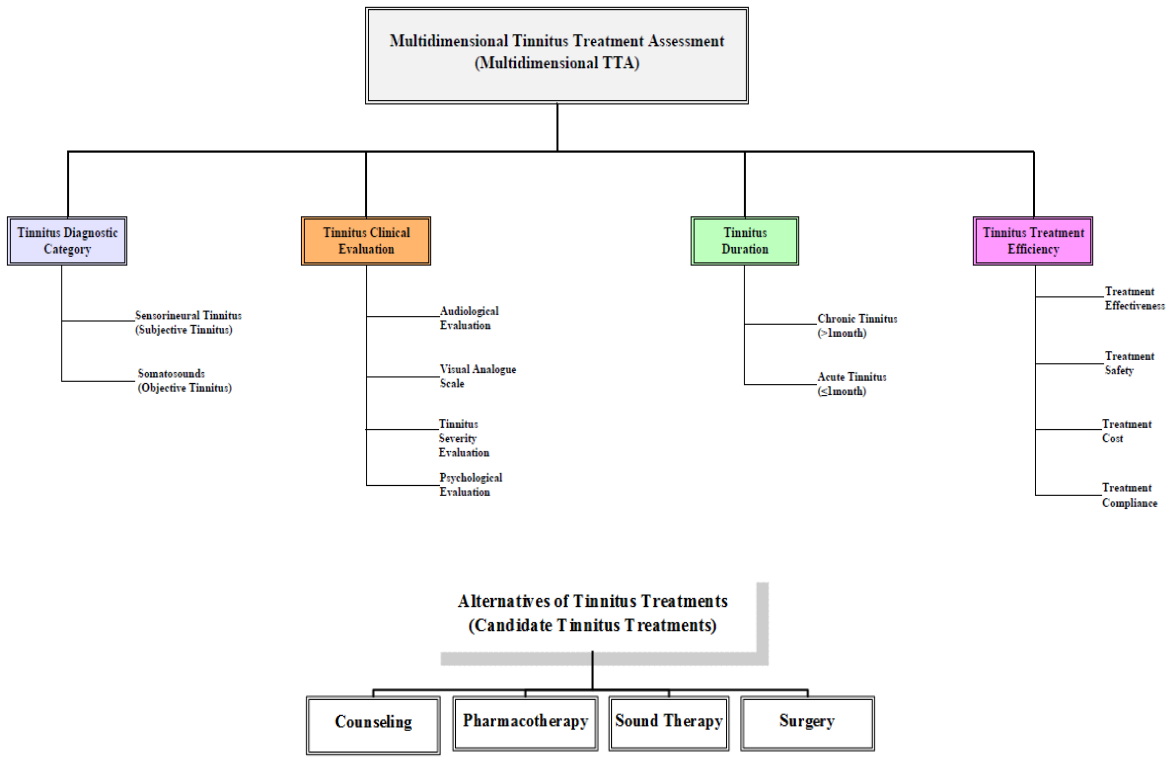


Figure 30: Final HDM for Multidimensional TTA with the Twelve Criteria without Sub-Criteria (or Factors)

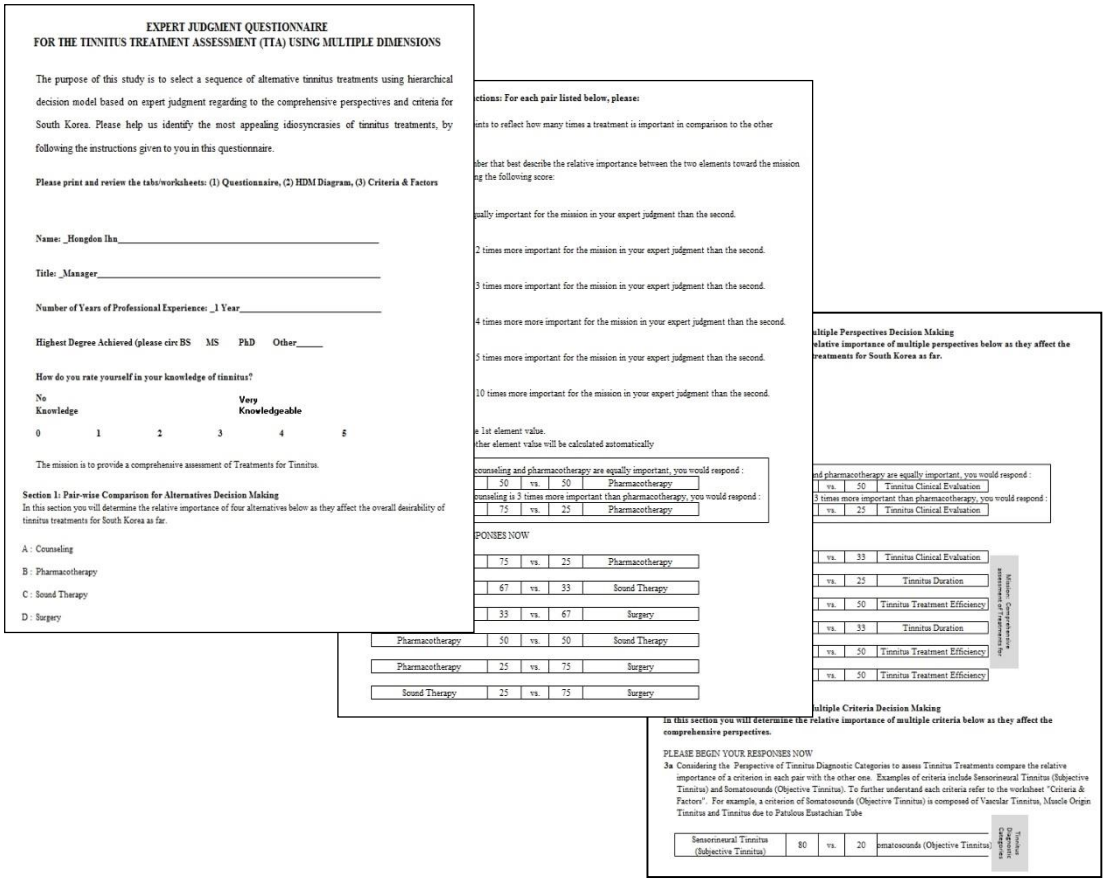
7.2 Organized Expert Panel and Judgment Quantification Instrument

The organization of expert panel is a fundamental process to compile the research instrument based on the experts' value judgments. To identify and qualify the listed candidates for a trustworthy panel of experts, the method of networking was applied, as detailed in Chapter 4. In particular, Korea's decision makers to evaluate the multidimensional tinnitus treatments are medical experts, who are otorhinolaryngologists with a specialty in tinnitus. In the Republic of Korea's otorhinolaryngological society of tinnitus study, 53 otorhinolaryngologists (Yoo et al.,

2013) are assumed to be the population of the HDM's experts for tinnitus treatment assessment (TTA) rather than a sample to obtain statistical data to respond to the research questionnaires. The experts of an HDM panel are Korea's otorhinolaryngologists who hold an MD and a PhD, and have acquired 15+ years of clinical experience and 5+ years of specialization in tinnitus, as well as international studies for tinnitus treatments. Furthermore, the organized panel of twelve experts is made up of medical professors from heterogeneous university colleges of medicine among 37 otorhinolaryngology departments in Korea's university hospitals (Yoo et al., 2013). Mark J. Clayton determined that the number of experts in a panel in a targeted population should be 5-10 specialized in a special field, who are academics (Clayton, 1997), and Nasir J. Sheikh suggested 10-15 experts to obtain robust data from a panel of experts in an HDM (Sheikh, Kim, & Kocaoglu, 2016). Thus, this study's panel of experts consists of twelve professional doctors from diverse university schools of medicine and public/private hospitals. Specifications of the HDM panel of experts is illustrated in Table 15.

Table 15: Specifications of the HDM Panel of Experts

Experts	Clinical Practices for Tinnitus	Specialty in Tinnitus	Degree/International Experience	Korea's otorhinolaryngological society for tinnitus study
Expert 1	25	10	MD, PhD/Korea and the US	Member
Expert 2	20	8	MD, PhD/Korea and the US	Member
Expert 3	21	15	MD, PhD/Korea and the US	Member
Expert 4	16	12	MD, PhD/Korea and the US	Member
Expert 5	15	11	MD, PhD/Korea	Member
Expert 6	16	10	MD, PhD/Korea and the US	Member
Expert 7	16	11	MD, PhD/Korea, Europe and the US	Member
Expert 8	18	10	MD, PhD/Korea and the US	Member
Expert 9	19	12	MD, PhD/Korea and the US	Member
Expert 10	18	10	MD, PhD/Korea and the US	Member
Expert 11	16	11	MD, PhD/Korea and the US	Member
Expert 12	16	10	MD, PhD/Korea	Member



EXPERT JUDGMENT QUESTIONNAIRE
FOR THE TINNITUS TREATMENT ASSESSMENT (TTA) USING MULTIPLE DIMENSIONS

The purpose of this study is to select a sequence of alternative tinnitus treatments using hierarchical decision model based on expert judgment regarding to the comprehensive perspectives and criteria for South Korea. Please help us identify the most appealing idiosyncrasies of tinnitus treatments, by following the instructions given to you in this questionnaire.

Please print and review the tabs/worksheets: (1) Questionnaire, (2) HDM Diagram, (3) Criteria & Factors

Name: _Hongdon Ihn_____

Title: _Manager_____

Number of Years of Professional Experience: _1 Year_____

Highest Degree Achieved (please circ BS MS PhD Other_____

How do you rate yourself in your knowledge of tinnitus?

No Knowledge 0 1 2 3 4 5 Very Knowledgeable

The mission is to provide a comprehensive assessment of Treatments for Tinnitus.

Section 1: Pair-wise Comparison for Alternatives Decision Making
In this section you will determine the relative importance of four alternatives below as they affect the overall desirability of tinnitus treatments for South Korea as far.

A : Counseling
B : Pharmacotherapy
C : Sound Therapy
D : Surgery

Figure 31: Judgment Quantification Instrument

The senior otorhinolaryngologist, Expert 1, provided first and second reviews for the initial and intermediate hierarchical decision-making model (HDM) frameworks and participated in the first interview to compile the expert judgments based on the research instrument, as illustrated in Figure 31. The expert feedback on the HDM framework and the judgment quantification instrument are reliable foundations for implementing the consensus-based expert judgment methodology using the Delphi technique. The 1,080 expert judgments from the panel of experts meet the validation requirement of less than the value of 0.1 of the level of inconsistency (LOI).

7.3 Collected Data Analysis and Validation

The pair-wise comparison metrics (PCM) software is an analytical tool to compute and measure the data of expert judgments with the research instrument. The Department of Engineering

Technology Management (ETM) at Portland State University developed this PCM software, as illustrated in Figure 32.

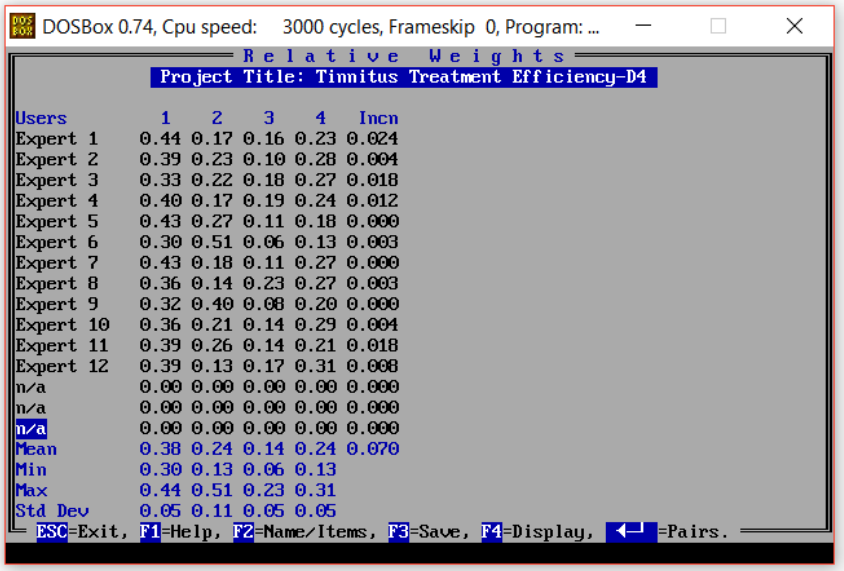


Figure 32: PCM Configuration as an Analytical Computation Software

7.3.1 Ranking of the four DCDE Dimensions: Korea's Otorhinolaryngologists' Worldview

The ranking and judgment quantification outcomes with respect to the DCDE dimensions are presented in this section. A twelve-member panel of decision makers was asked to determine the relative priorities of the four DCDE dimensions to attain the mission of multidimensional tinnitus treatment assessment. The relative ranking values of the dimensions with respect to the mission meet the level of inconsistency (LOI) and the level of disagreement (LOD), which are less than the value of 0.10, as illustrated in Table 16. The PCM is applied for evaluating expert judgments for TTA and analyzing the relative ranking value with respect to each dimension (see Table 16, and Figures 33 and 34). The panel of experts determined the clinical dimension (D2) as the top-ranked dimension. The diagnostic and duration dimensions (D1 and D3) both made up the second place. The efficiency dimension (D4) held the lowest place. The relative evaluation presents the ranking and contribution to TTA as well as the priorities of the DCDE dimensions, as shown in Table 17. The values of the DCDE dimensions' relative ranking are

more than 15% of the contribution rate for TTA with respect to the mission. These values suggest that all dimensions play a significant role, since every single dimension has a rate above 15%.

Table 16: Relative Ranking Values for the DCDE Dimensions with Respect to the Mission

Assessment of Tinnitus Treatments using Multiple Dimensions	**Diagnostic Dimension**	**Clinical Dimension**	**Duration Dimension**	**Efficiency Dimension**	**Inconsistency**
Expert 1	0.19	0.43	0.23	0.15	0.008
Expert 2	0.22	0.48	0.13	0.18	0.004
Expert 3	0.32	0.36	0.15	0.17	0.005
Expert 4	0.10	0.54	0.14	0.22	0.030
Expert 5	0.20	0.46	0.28	0.06	0.004
Expert 6	0.47	0.16	0.31	0.06	0.008
Expert 7	0.34	0.51	0.06	0.09	0.000
Expert 8	0.21	0.31	0.35	0.13	0.008
Expert 9	0.16	0.38	0.06	0.40	0.028
Expert 10	0.13	0.40	0.26	0.21	0.012
Expert 11	0.13	0.44	0.20	0.23	0.007
Expert 12	0.11	0.34	0.41	0.14	0.051
Mean	0.21	0.40	0.21	0.17	
Minimum	0.10	0.16	0.06	0.06	
Maximum	0.47	0.54	0.41	0.40	
Standard Deviation	0.11	0.10	0.11	0.09	
Disagreement					0.10

Assessment of the Four DCDE Dimensions				
Tinnitus Diagnostic Categories (D1)	Mean	0.21	No. of SPL	12
	Std. Dev.	0.11	CI	90[1)]
	CI Lower	0.15		
	CI Upper	0.27		
Tinnitus Clinical Evaluation (D2)	Mean	0.40	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.34		
	CI Upper	0.46		
Tinnitus Duration (D3)	Mean	0.21	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.15		
	CI Upper	0.27		
Tinnitus Treatment Efficiency (D4)	Mean	0.17	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.11		
	CI Upper	0.23		

[1)] A 90% confidence interval

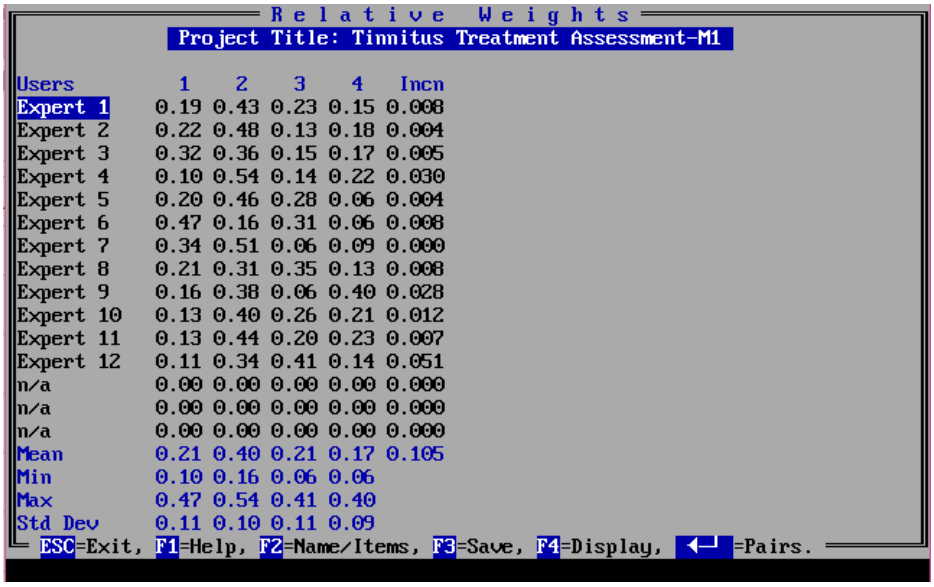


Figure 33: PCM Data Analysis Results with Respect to the Mission

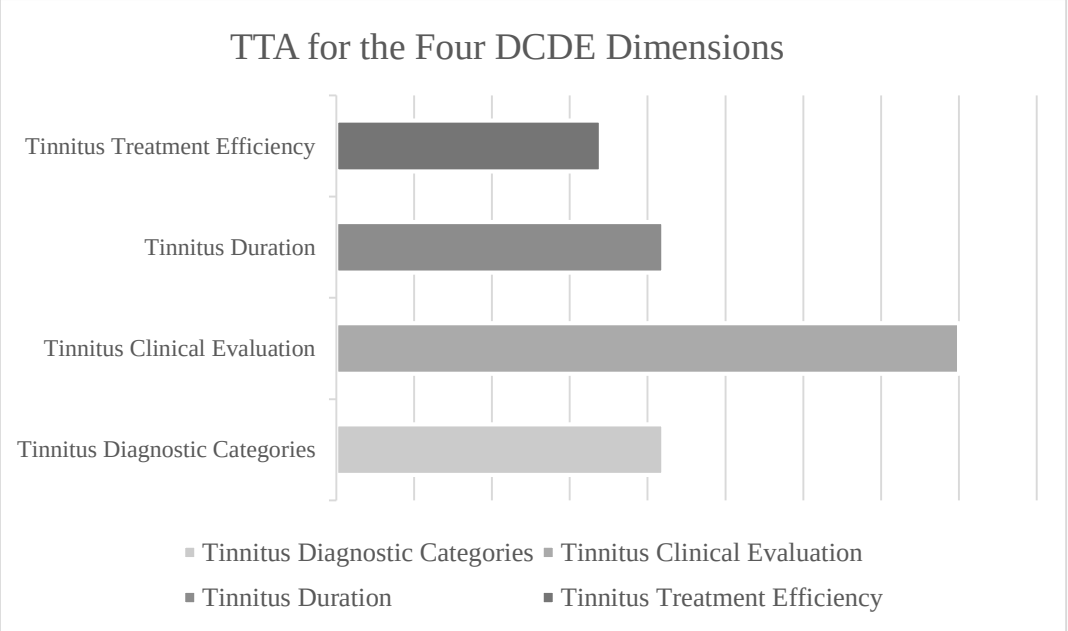


Figure 34: TTA for the Four DCDE Dimensions

Table 17: DCDE Dimensional Values for Relative Evaluation

Ranking	DCDE Dimensions	Dimension Values	Relative Evaluation
1	D2: Clinical Dimension	40	100%
2	D1: Diagnostic Dimension	21.5	54%
2	D3: Duration Dimension	21.5	54%
4	D4: Efficiency Dimension	17	43%

7.3.2 Ranking of the Two Criteria with Respect to the Diagnostic Dimension

Under the diagnostic dimension, the two criteria of somatosounds and sensorineural tinnitus are subsumed. The relative value judgments result from a panel of experts, as shown in Table 18. The criterion of somatosounds (C11) is more than 4.8 times the priorities compared to the criterion of sensorineural tinnitus (C12), as illustrated in Figure 35.

Table 18: Relative Ranking Values for the Criteria with Respect to the Diagnostic Dimension (D1)

Diagnostic Dimension (D1)	Sensorineural Tinnitus (C11)	Somatosounds (C12)	Inconsistency
Expert 1	0.80	0.20	0.000
Expert 2	0.80	0.20	0.000
Expert 3	0.80	0.20	0.000
Expert 4	0.70	0.30	0.000
Expert 5	0.90	0.10	0.000
Expert 6	0.80	0.20	0.000
Expert 7	0.90	0.10	0.000
Expert 8	0.91	0.09	0.000
Expert 9	0.80	0.20	0.000
Expert 10	0.90	0.10	0.000
Expert 11	0.90	0.10	0.000
Expert 12	0.80	0.20	0.000
Mean	0.83	0.17	
Minimum	0.70	0.09	
Maximum	0.91	0.30	
Standard Deviation	0.07	0.07	

Assessment of Diagnostic Dimension-Criteria				
Sensorineural Tinnitus: Subjective Tinnitus (C11)	Mean	0.83	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.80		
	CI Upper	0.87		
Somatosounds: Objective Tinnitus (C12)	Mean	0.17	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.13		
	CI Upper	0.20		

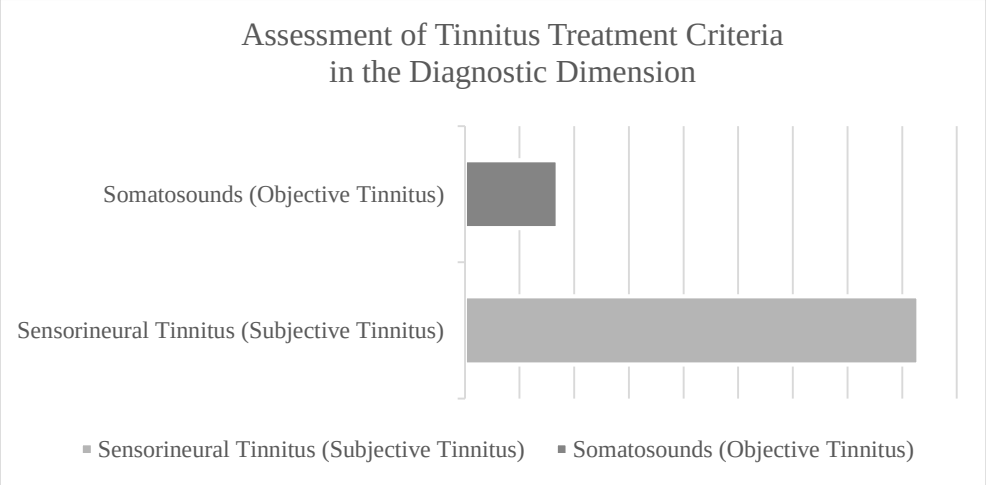


Figure 35: TTA for the Two Criteria with Respect to the Diagnostic Dimension

7.3.3 Ranking of the Four Criteria with Respect to the Clinical Evaluation Dimension

The resulting relative ranking values of the four criteria with respect to the clinical evaluation dimension with LOI and LOD are illustrated in Table 19 and Figure 36. The first-ranked criterion of audiological evaluation (C21) is 1.5 to 2.7 times higher than the other three criteria. The sum value of visual analogue scale (VAS) (C22) and psychological evaluation (C24) is almost equivalent to the value of audiological evaluation (C21), as illustrated in Figure 37.

Table 19: Relative Ranking Values for the Criteria with Respect to the Clinical Evaluation Dimension (D2)

Clinical Dimension (D2)	**Audiological Evaluation (C21)**	**Visual Analogue Scale (VAS) (C22)**	**Tinnitus Severity Evaluation (C23)**	**Psychological Evaluation (C24)**	**Inconsistency**
Expert 1	0.22	0.16	0.36	0.26	0.038
Expert 2	0.39	0.14	0.29	0.19	0.004
Expert 3	0.25	0.39	0.25	0.10	0.000
Expert 4	0.33	0.17	0.24	0.26	0.049
Expert 5	0.58	0.08	0.21	0.13	0.005
Expert 6	0.50	0.14	0.26	0.09	0.015
Expert 7	0.43	0.18	0.27	0.11	0.000
Expert 8	0.65	0.15	0.18	0.02	0.006
Expert 9	0.40	0.20	0.24	0.16	0.000
Expert 10	0.52	0.18	0.15	0.14	0.023
Expert 11	0.44	0.11	0.36	0.09	0.008
Expert 12	0.23	0.14	0.39	0.23	0.021
Mean	0.41	0.17	0.27	0.15	
Minimum	0.22	0.08	0.15	0.02	
Maximum	0.65	0.39	0.39	0.26	
Standard Deviation	0.14	0.08	0.07	0.07	
Disagreement					0.09

Assessment of Clinical Dimension-Criteria				
Audiological Evaluation (C21)	Mean	0.41	No. of SPL	12
	Std. Dev.	0.14	CI	90
	CI Lower	0.34		
	CI Upper	0.48		
Visual Analogue Scale (C22)	Mean	0.17	No. of SPL	12
	Std. Dev.	0.08	CI	90
	CI Lower	0.13		
	CI Upper	0.21		
Tinnitus Severity Evaluation (C23)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.23		
	CI Upper	0.31		
Psychological Evaluation (C24)	Mean	0.15	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.11		
	CI Upper	0.19		

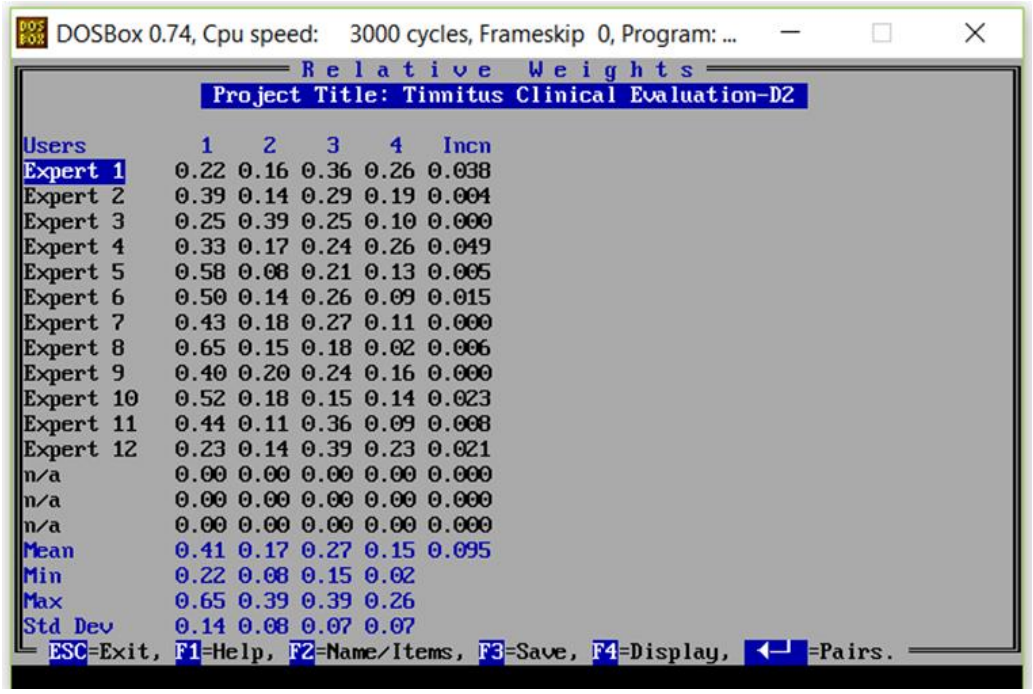


Figure 36: PCM Data Analysis Results with Respect to D2

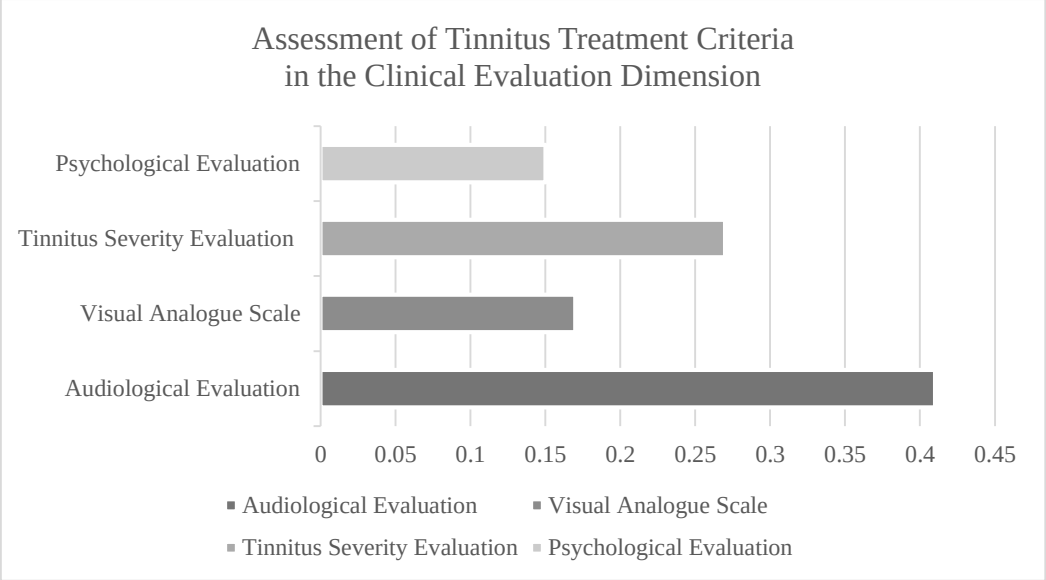


Figure 37: TTA for the Four Criteria with Respect to the Clinical Evaluation Dimension

7.3.4 Ranking of the Two Criteria with Respect to the Duration Dimension

The resulting relative ranking values of the two criteria, statistical analysis data, LOI and LOD are illustrated with respect to the duration dimension in Table 20. The criterion for chronic tinnitus (C31) is over 3.8 times more important than the criterion for acute tinnitus (C32), as illustrated in Figure 38.

Table 20: Relative Ranking Values for the Two Criteria with Respect to the Duration Dimension (D3)

Duration Dimension (D2)	Chronic Tinnitus (C31)	Acute Tinnitus (C32)	Inconsistency
Expert 1	0.80	0.2	0.000
Expert 2	0.80	0.2	0.000
Expert 3	0.70	0.3	0.000
Expert 4	0.40	0.6	0.000
Expert 5	0.90	0.1	0.000
Expert 6	0.80	0.2	0.000
Expert 7	0.95	0.05	0.000
Expert 8	0.95	0.05	0.000
Expert 9	0.70	0.3	0.000
Expert 10	0.80	0.2	0.000
Expert 11	0.90	0.1	0.000
Expert 12	0.80	0.2	0.000
Mean	0.79	0.21	
Minimum	0.40	0.05	
Maximum	0.95	0.60	
Standard Deviation	0.15	0.15	

Assessment of Duration Dimension-Criteria				
Chronic Tinnitus (C31)	Mean	0.79	No. of SPL	12
	Std. Dev.	0.15	CI	90
	CI Lower	0.71		
	CI Upper	0.87		
Acute Tinnitus (C32)	Mean	0.21	No. of SPL	12
	Std. Dev.	0.15	CI	90
	CI Lower	0.13		
	CI Upper	0.29		

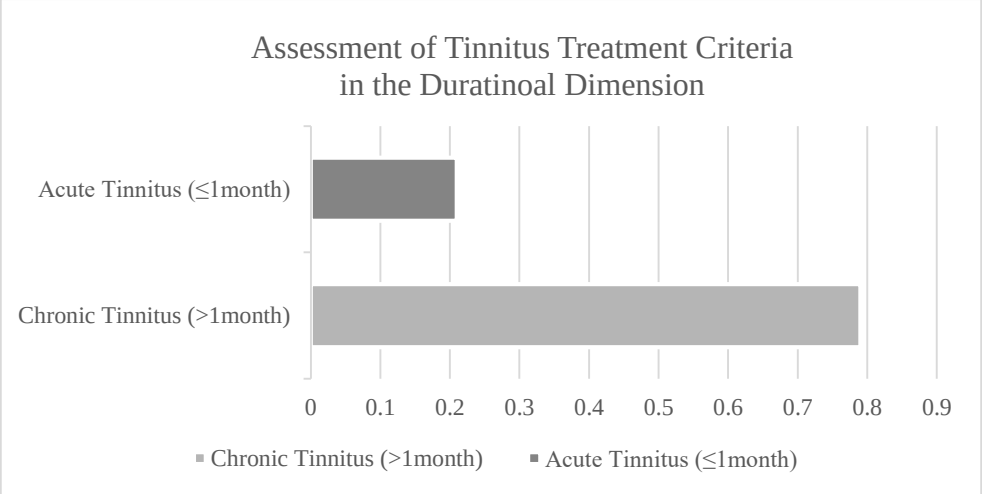


Figure 38: TTA for the Two Criteria with Respect to the Durational Dimension

7.3.5 Ranking of the Four Criteria with Respect to the Efficiency Dimension

The last efficiency dimension consists of four criteria: tinnitus treatment effectiveness or efficacy, treatment safety, treatment cost and treatment compliance. The experts judged each criterion based on the ratio-scale pair-wise comparisons and the relative fractional ranking values are calculated ranging from 0.14 to 0.38, which total a constant sum of 1.00, as shown in Table 21. The result of the LOD is eminently satisfactory; it is the value of 0.04, less than half of 0.10. The PCM for the evaluation of the panel of experts computes the relative ranking values with respect to each criterion, as illustrated in Figures 39 and 40.

Table 21: Relative Ranking Values for the Four Criteria with Respect to the Efficiency Dimension (D4)

Efficiency Dimension (D4)	**Treatment Effectiveness (C41)**	**Treatment Safety (C42)**	**Treatment Cost (C43)**	**Treatment Compliance (C44)**	**Inconsistency**
Expert 1	0.44	0.17	0.16	0.23	0.024
Expert 2	0.39	0.23	0.10	0.28	0.004
Expert 3	0.33	0.22	0.18	0.27	0.018
Expert 4	0.40	0.17	0.19	0.24	0.012
Expert 5	0.43	0.27	0.11	0.18	0.000
Expert 6	0.30	0.51	0.06	0.13	0.003
Expert 7	0.43	0.18	0.11	0.27	0.000
Expert 8	0.36	0.14	0.23	0.27	0.003
Expert 9	0.32	0.40	0.08	0.20	0.000
Expert 10	0.36	0.21	0.14	0.29	0.004
Expert 11	0.39	0.26	0.14	0.21	0.018
Expert 12	0.39	0.13	0.17	0.31	0.008
Mean	0.38	0.24	0.14	0.24	
Minimum	0.30	0.13	0.06	0.13	
Maximum	0.44	0.51	0.23	0.31	
Standard Deviation	0.05	0.11	0.05	0.05	
Disagreement					0.07

Assessment of Efficiency Dimension-Criteria				
Treatment Effectiveness (C41)	Mean	0.38	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.35		
	CI Upper	0.41		
Treatment Safety (C42)	Mean	0.24	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.18		
	CI Upper	0.30		
Treatment Cost (C43)	Mean	0.14	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.11		
	CI Upper	0.17		
Tinnitus Treatment Efficiency (D4)	Mean	0.24	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.21		
	CI Upper	0.27		

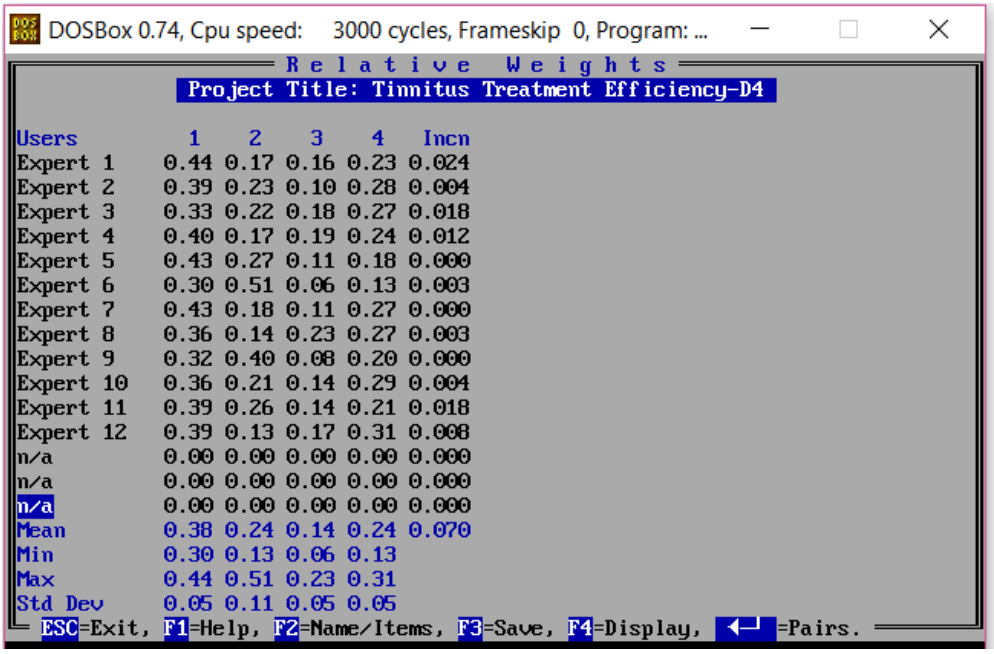


Figure 39: PCM Data Analysis Results with Respect to D4

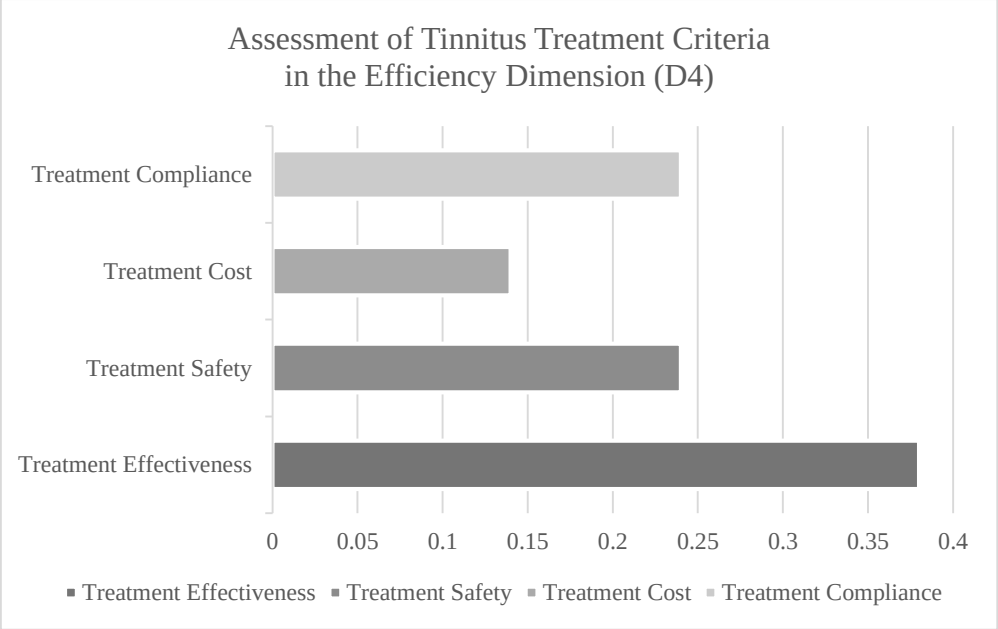


Figure 40: TTA for the Four Criteria with Respect to the Efficiency Dimension

7.3.6 Analysis Results of the Four DCDE Dimensions and the Associated Multiple Criteria

The overall rankings of multiple dimensions with respect to the mission to TTA reveal that the clinical evaluation dimension (D2) is much more important than the other three dimensions, diagnostic dimension (D1), duration dimension (D3) and efficiency dimension (D4). The relative ranking of each criterion in the four DCDE dimensions is recapitulated with the classification of top, middle, and bottom criteria in the competitive consideration of multiple dimensions, as shown in Table 22. The four relative ranking values (RRV) with respect to the DCDE dimensions revealed that all RRV of the four dimensions, more than 0.15, contributed significantly to a comprehensive TTA with the relative importance to the associated twelve criteria , as detailed in Table 23.

Table 22: Top, Middle, and Bottom Criteria with Respect to the four DCDE Dimensions

DCDE Dimensions	Top Criteria	Middle Criteria	Bottom Criteria
D1: Tinnitus Diagnostic Categories	C11: Sensorineural Tinnitus (Subjective Tinnitus)		C12: Somatosounds (Objective Tinnitus)
D2: Tinnitus Clinical Evaluation	C21: Audiological Evaluation	C23: Tinnitus Severity Evaluation C22: Visual Analogue Scale	C24: Psychological Evaluation
D3: Tinnitus Duration	C31: Chronic Tinnitus (>1month)		C32: Acute Tinnitus (≤1month)
D4: Tinnitus Treatment Efficiency	C41: Treatment Effectiveness	C44: Treatment Compliance C42: Treatment Safety	C43: Treatment Cost

Table 23: Relative Ranking Values of each Dimension and Criterion to Contribute to a Comprehensive TTA

Dimension	Relative importance to dimension		Criterion	Relative importance to criterion	
	Rank	Value		Rank	Value
Tinnitus Diagnostic Category	2	0.215	− Sensorineural Tinnitus (Subjective Tinnitus)	1	0.18
			− Somatosounds Tinnitus (Objective Tinnitus)	2	0.04
Tinnitus Clinical Evaluation	1	0.400	− Audiological Evaluation	1	0.16
			− Visual Analogue Scale (VAS)	3	0.07
			− Tinnitus Severity Evaluation	2	0.11
			− Psychological Evaluation	4	0.06
Tinnitus Duration	2	0.215	− Chronic Tinnitus (>1month)	1	0.17
			− Acute Tinnitus (≤1month)	2	0.05
Tinnitus Treatment Efficiency	4	0.170	− Treatment Effectiveness	1	0.07
			− Treatment Safety	2	0.04
			− Treatment Cost	4	0.02
			− Treatment Compliance	2	0.04

7.3.7 Calculated Treatment Values of the Alternatives of Candidate Tinnitus Treatments

With respect to each criterion associated with the four DCDE dimensions, there are four alternatives of candidate tinnitus treatments, which are (1) T1: counseling, (2) T2: pharmacotherapy, (3) T3: sound therapy and (4) T4: surgery. The ranking values represent the gaps in relative importance of each candidate treatment, as illustrated in Tables 24-35 and Figures 41-64. These PCM outputs indicate the relative importance of alternatives with respect to each criterion and the fundamental data to calculate the final treatment values (TV_n).

In particular, the ranking value of 4% shows that surgical treatment is the least used approach to treat sensorineural or subjective tinnitus (C11). The ranking values for counseling (T1), pharmacotherapy (T2) and sound therapy (T3) are 6.25 to 11.25 times more than the value of 4% for surgery (T4), as shown in Table 24 and Figures 41-42.

Table 24: Relative Ranking Values of the Alternatives with Respect to the Criterion of Sensorineural Tinnitus (C11)

Sensorineural Tinnitus (C11)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.32	0.26	0.39	0.04	0.008
Expert 2	0.48	0.14	0.34	0.04	0.006
Expert 3	0.55	0.15	0.26	0.05	0.014
Expert 4	0.39	0.40	0.17	0.04	0.033
Expert 5	0.58	0.14	0.25	0.03	0.003
Expert 6	0.43	0.29	0.25	0.03	0.011
Expert 7	0.49	0.18	0.30	0.03	0.010
Expert 8	0.49	0.42	0.05	0.04	0.000
Expert 9	0.28	0.3	0.31	0.04	0.004
Expert 10	0.50	0.17	0.29	0.03	0.042
Expert 11	0.44	0.22	0.30	0.03	0.016
Expert 12	0.51	0.29	0.17	0.03	0.012
Mean	0.45	0.25	0.26	0.04	
Minimum	0.28	0.14	0.05	0.03	
Maximum	0.58	0.42	0.39	0.05	
Standard Deviation	0.09	0.10	0.09	0.01	
Disagreement					0.08

Assessment of Sensorineural Tinnitus Criterion-Alternatives				
Counseling (T1)	Mean	0.45	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.42		
	CI Upper	0.48		
Pharmacotherapy (T2)	Mean	0.25	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.19		
	CI Upper	0.31		
Sound Therapy (T3)	Mean	0.26	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.23		
	CI Upper	0.29		
Surgery (T4)	Mean	0.04	No. of SPL	12
	Std. Dev.	0.05	CI	90
	CI Lower	0.01		
	CI Upper	0.07		

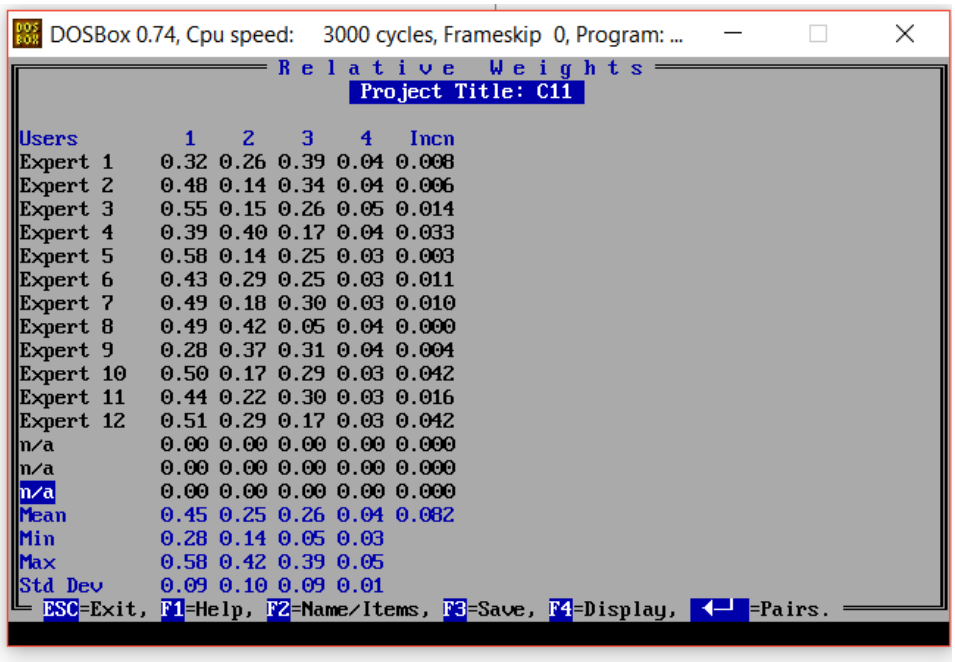


Figure 41: PCM Data Analysis Results with Respect to C11

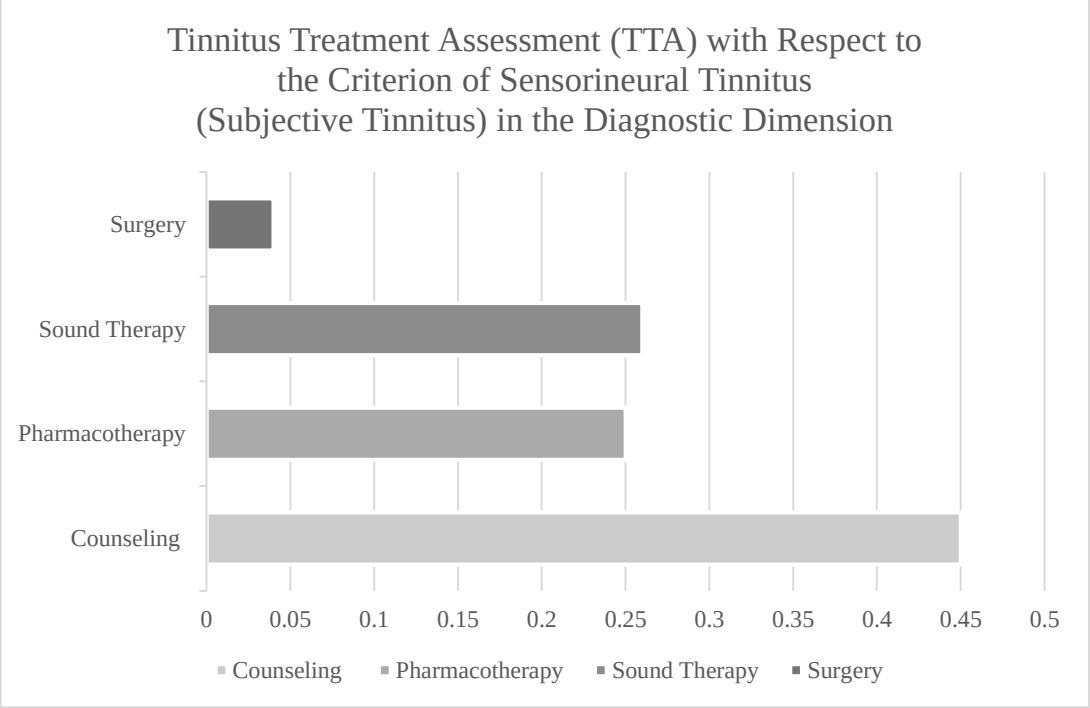


Figure 42: TTA with respect to the Criterion of Sensorineural Tinnitus (C11)

Table 25: Relative Ranking Values of the Alternatives with Respect to the Criterion of Somatosounds (C12)

Somatosounds (C12)	Counseling (T1)	Pharmacotherapy (T2)	Sound Therapy (T3)	Surgery (T4)	Inconsistency
Expert 1	0.15	0.40	0.26	0.19	0.017
Expert 2	0.41	0.34	0.15	0.10	0.005
Expert 3	0.13	0.40	0.23	0.23	0.033
Expert 4	0.26	0.35	0.35	0.04	0.004
Expert 5	0.49	0.31	0.14	0.05	0.017
Expert 6	0.46	0.21	0.29	0.03	0.004
Expert 7	0.58	0.07	0.03	0.32	0.004
Expert 8	0.80	0.06	0.01	0.12	0.052
Expert 9	0.20	0.36	0.26	0.18	0.012
Expert 10	0.39	0.13	0.17	0.31	0.008
Expert 11	0.45	0.22	0.03	0.30	0.012
Expert 12	0.40	0.33	0.07	0.19	0.022
Mean	0.39	0.27	0.17	0.17	
Minimum	0.13	0.06	0.01	0.03	
Maximum	0.80	0.40	0.35	0.32	
Standard Deviation	0.19	0.12	0.11	0.11	
Disagreement					0.13

Assessment of Somatosounds Criterion-Alternatives				
Counseling (T1)	Mean	0.39	No. of SPL	12
	Std. Dev.	0.19	CI	90
	CI Lower	0.29		
	CI Upper	0.49		
Pharmacotherapy (T2)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.12	CI	90
	CI Lower	0.21		
	CI Upper	0.33		
Sound Therapy (T3)	Mean	0.17	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.11		
	CI Upper	0.23		
Surgery (T4)	Mean	0.17	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.11		
	CI Upper	0.23		

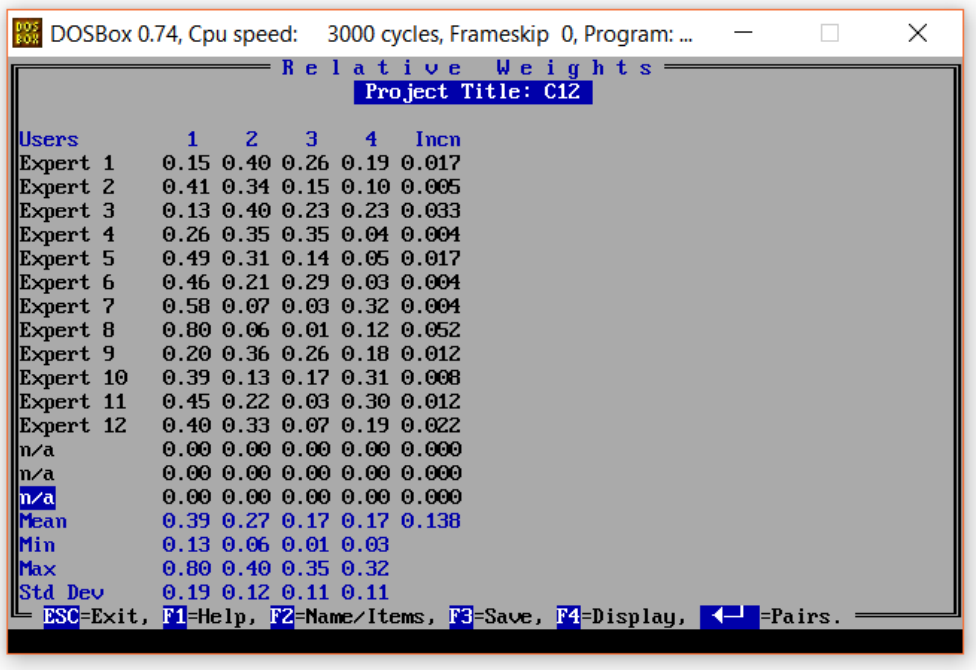


Figure 43: PCM Data Analysis Results with Respect to C12

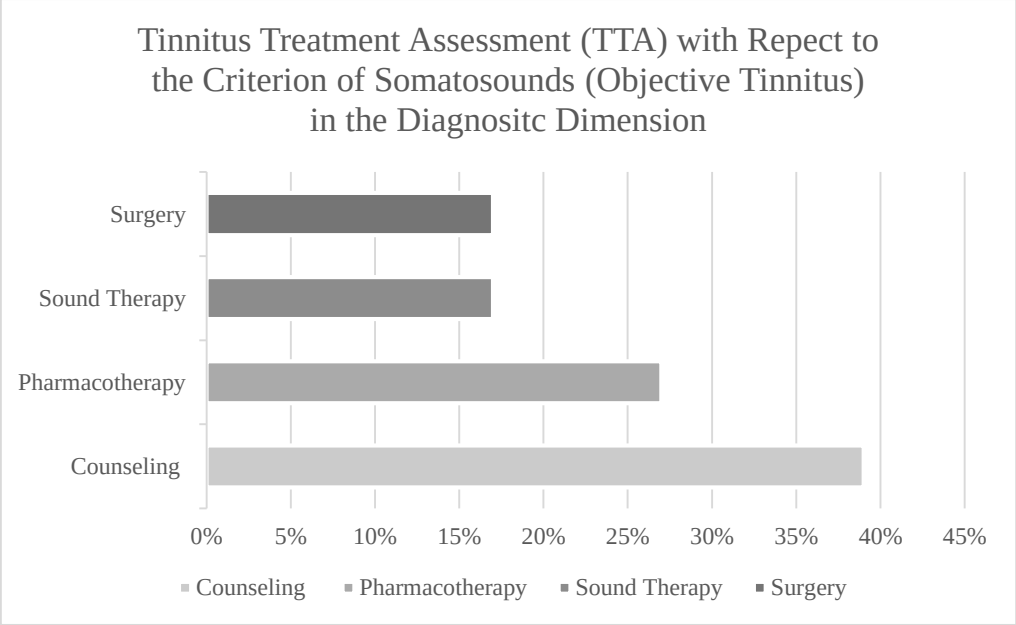


Figure 44: TTA with Respect to the Criterion of Somatosounds (C12)

Table 26: Relative Ranking Values of the Alternatives with Respect to the Criterion of Audiological Evaluation (C21)

Audiological Evaluation (C21)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.32	0.29	0.36	0.04	0.013
Expert 2	0.51	0.13	0.30	0.06	0.003
Expert 3	0.56	0.18	0.19	0.06	0.020
Expert 4	0.42	0.32	0.21	0.06	0.022
Expert 5	0.58	0.13	0.25	0.03	0.008
Expert 6	0.45	0.23	0.30	0.02	0.011
Expert 7	0.49	0.18	0.30	0.03	0.010
Expert 8	0.49	0.42	0.05	0.04	0.000
Expert 9	0.26	0.37	0.33	0.04	0.006
Expert 10	0.46	0.18	0.31	0.06	0.013
Expert 11	0.44	0.22	0.30	0.03	0.016
Expert 12	0.38	0.21	0.35	0.06	0.030
Mean	0.45	0.24	0.27	0.04	
Minimum	0.26	0.13	0.05	0.02	
Maximum	0.58	0.42	0.36	0.06	
Standard Deviation	0.09	0.09	0.09	0.01	
Disagreement					0.07

Assessment of Audiological Evaluation Criterion-Alternatives				
Counseling (T1)	Mean	0.45	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.40		
	CI Upper	0.50		
Pharmacotherapy (T2)	Mean	0.24	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.19		
	CI Upper	0.29		
Sound Therapy (T3)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.22		
	CI Upper	0.32		
Surgery (T4)	Mean	0.04	No. of SPL	12
	Std. Dev.	0.01	CI	90
	CI Lower	0.03		
	CI Upper	0.05		

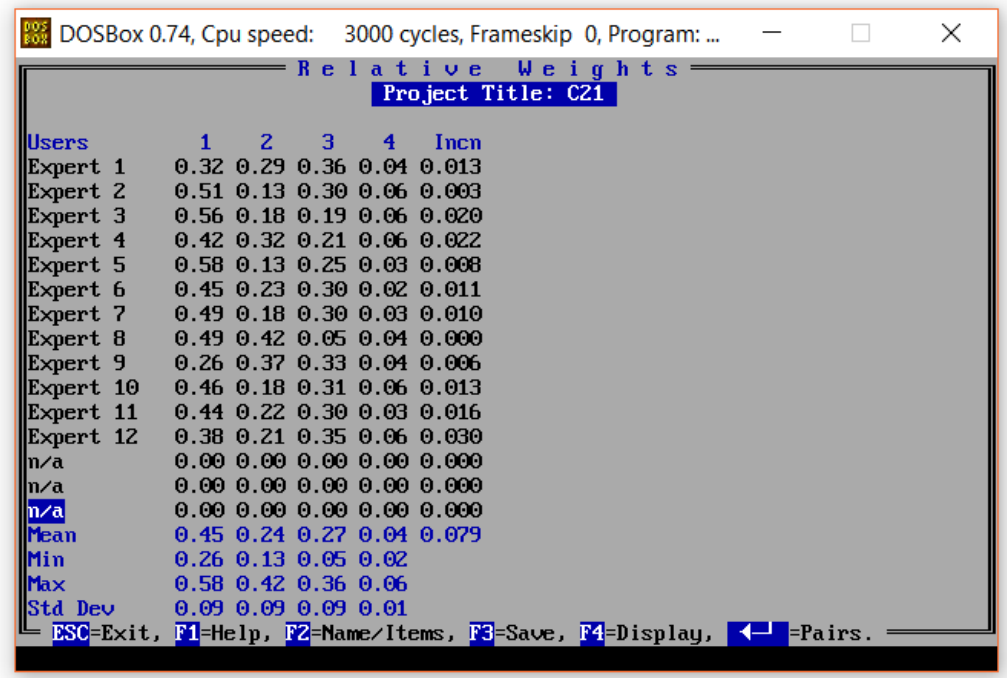


Figure 45: PCM Data Analysis Results with Respect to C21

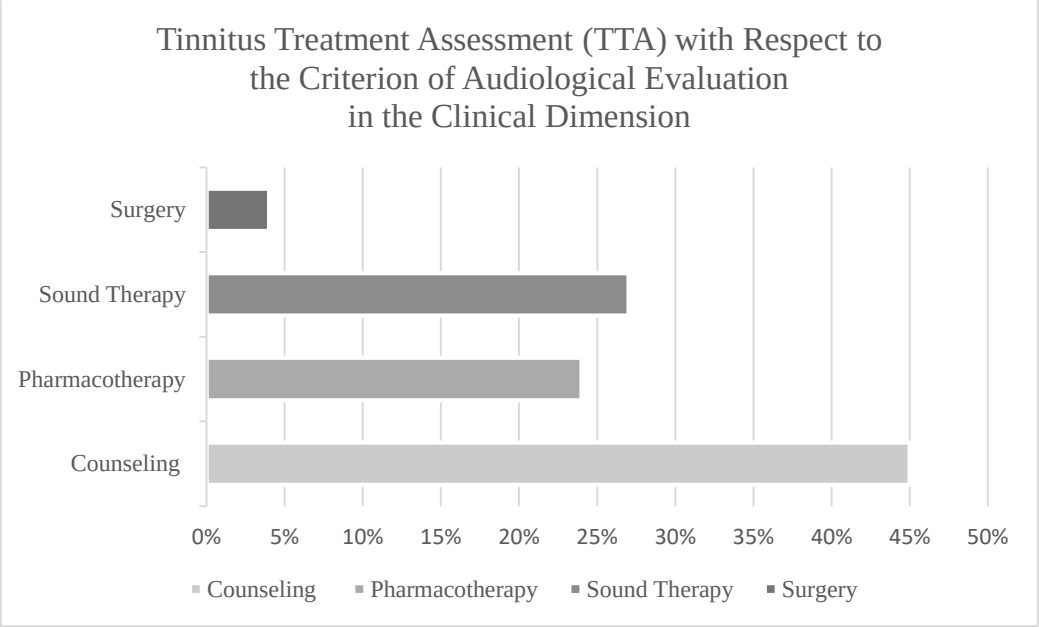


Figure 46: TTA with Respect to the Criterion of Audiological Evaluation (C21)

Table 27: Relative Ranking Values of the Alternatives with Respect to the Criterion of Visual Analogue Scale (VAS) (C22)

Visual Analogue Scale (C22)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.32	0.29	0.36	0.04	0.013
Expert 2	0.51	0.17	0.27	0.05	0.012
Expert 3	0.56	0.18	0.19	0.06	0.020
Expert 4	0.37	0.28	0.28	0.08	0.004
Expert 5	0.58	0.13	0.25	0.03	0.008
Expert 6	0.37	0.36	0.24	0.03	0.022
Expert 7	0.46	0.21	0.31	0.02	0.000
Expert 8	0.50	0.47	0.03	0.00	0.001
Expert 9	0.19	0.44	0.31	0.06	0.000
Expert 10	0.46	0.20	0.28	0.06	0.004
Expert 11	0.39	0.30	0.27	0.03	0.013
Expert 12	0.47	0.27	0.22	0.03	0.022
Mean	0.43	0.28	0.25	0.04	
Minimum	0.19	0.13	0.03	0.00	
Maximum	0.58	0.47	0.36	0.08	
Standard Deviation	0.11	0.11	0.08	0.02	
Disagreement					0.08

Assessment of Visual Analogue Scale Criterion-Alternatives				
Counseling (T1)	Mean	0.43	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.37		
	CI Upper	0.49		
Pharmacotherapy (T2)	Mean	0.28	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.22		
	CI Upper	0.34		
Sound Therapy (T3)	Mean	0.25	No. of SPL	12
	Std. Dev.	0.08	CI	90
	CI Lower	0.21		
	CI Upper	0.29		
Surgery (T4)	Mean	0.04	No. of SPL	12
	Std. Dev.	0.02	CI	90
	CI Lower	0.03		
	CI Upper	0.05		

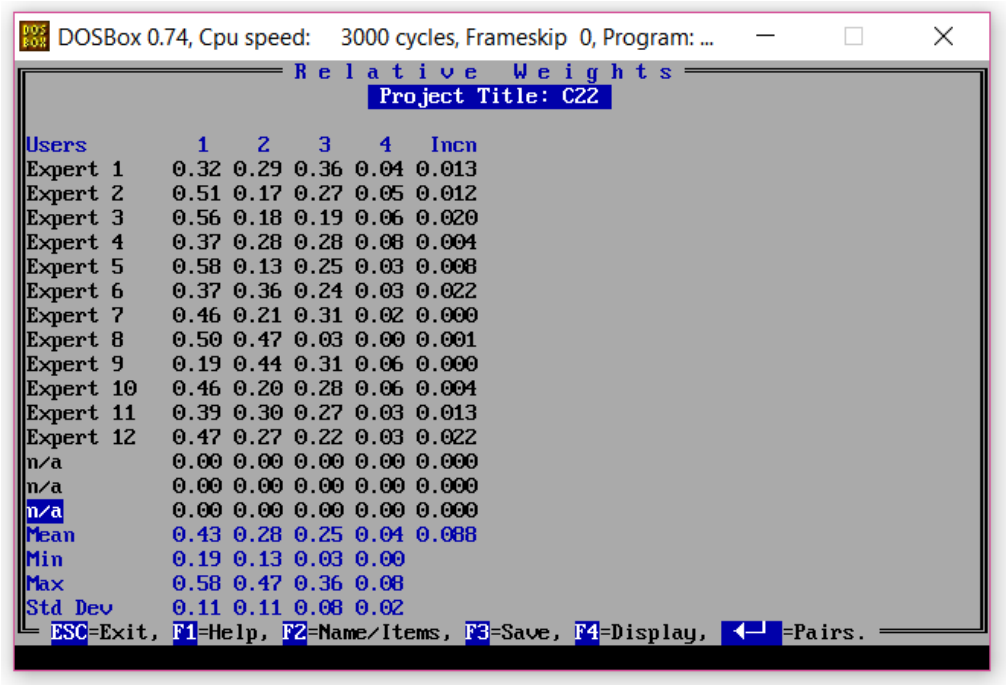


Figure 47: PCM Data Analysis with Respect to the C22

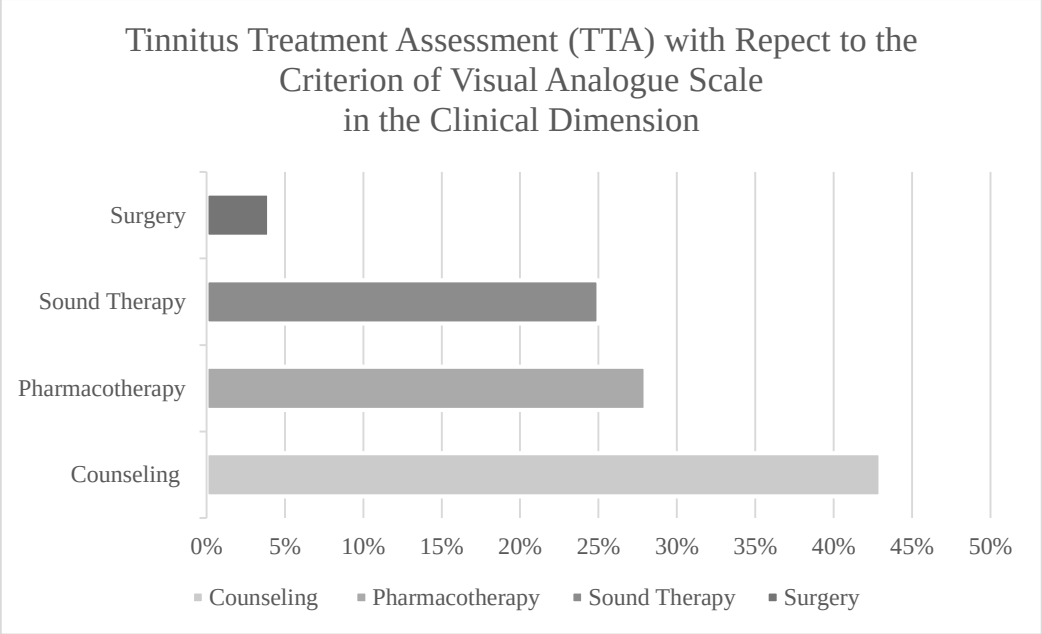


Figure 48: TTA with Respect to the Criterion of Visual Analogue Scale (C22)

Table 28: Relative Ranking Values of the Alternatives with Respect to the Criterion of Tinnitus Severity Evaluation (C23)

Tinnitus Severity Evaluation (C23)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.35	0.35	0.26	0.04	0.004
Expert 2	0.61	0.14	0.19	0.06	0.006
Expert 3	0.56	0.18	0.19	0.06	0.020
Expert 4	0.37	0.28	0.28	0.08	0.004
Expert 5	0.56	0.17	0.24	0.03	0.007
Expert 6	0.37	0.38	0.21	0.03	0.021
Expert 7	0.58	0.14	0.25	0.03	0.003
Expert 8	0.54	0.42	0.03	0.01	0.010
Expert 9	0.19	0.44	0.31	0.06	0.000
Expert 10	0.51	0.17	0.27	0.05	0.012
Expert 11	0.39	0.30	0.27	0.03	0.013
Expert 12	0.56	0.22	0.19	0.03	0.046
Mean	0.47	0.27	0.22	0.04	
Minimum	0.19	0.14	0.03	0.01	
Maximum	0.61	0.44	0.31	0.08	
Standard Deviation	0.13	0.11	0.07	0.02	
Disagreement					0.09

Assessment of Tinnitus Severity Evaluation Criterion-Alternatives				
Counseling (T1)	Mean	0.47	No. of SPL	12
	Std. Dev.	0.13	CI	90
	CI Lower	0.40		
	CI Upper	0.54		
Pharmacotherapy (T2)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.21		
	CI Upper	0.33		
Sound Therapy (T3)	Mean	0.22	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.18		
	CI Upper	0.26		
Surgery (T4)	Mean	0.04	No. of SPL	12
	Std. Dev.	0.02	CI	90
	CI Lower	0.03		
	CI Upper	0.05		

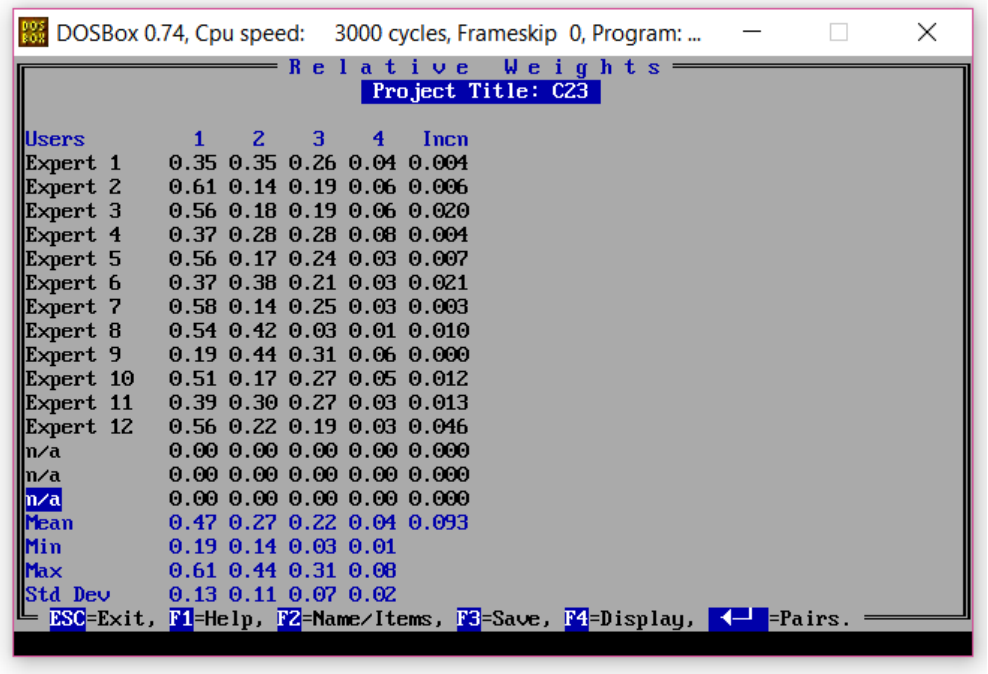


Figure 49: PCM Data Analysis Results with Respect to C23

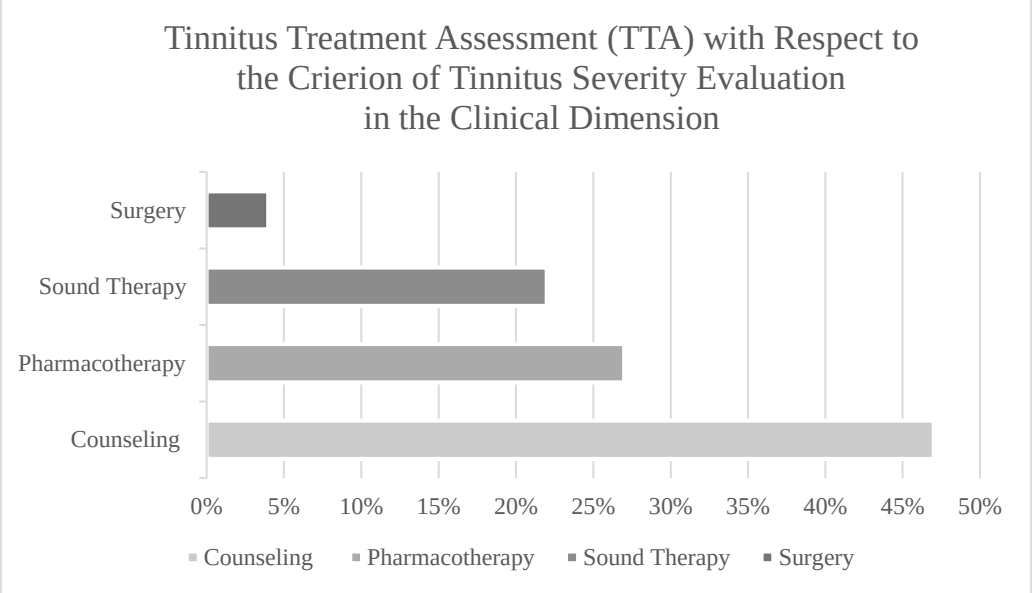


Figure 50: TTA with Respect to the Criterion of Tinnitus Severity Evaluation (C23)

Table 29: Relative Ranking Values of the Alternatives with Respect to the Criterion of Psychological Evaluation (C24)

Psychological Evaluation (C24)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.30	0.46	0.20	0.03	0.035
Expert 2	0.45	0.37	0.15	0.03	0.053
Expert 3	0.50	0.27	0.17	0.05	0.017
Expert 4	0.43	0.31	0.23	0.03	0.014
Expert 5	0.61	0.22	0.15	0.03	0.006
Expert 6	0.41	0.34	0.23	0.02	0.004
Expert 7	0.56	0.16	0.25	0.03	0.005
Expert 8	0.50	0.47	0.03	0.00	0.001
Expert 9	0.13	0.57	0.29	0.01	0.002
Expert 10	0.46	0.20	0.28	0.06	0.004
Expert 11	0.40	0.38	0.20	0.02	0.006
Expert 12	0.50	0.29	0.17	0.03	0.042
Mean	0.44	0.34	0.19	0.03	
Minimum	0.13	0.16	0.03	0.00	
Maximum	0.61	0.57	0.29	0.06	
Standard Deviation	0.12	0.12	0.07	0.02	
Disagreement					0.09

Assessment of Psychological Evaluation Criterion-Alternatives				
Counseling (T1)	Mean	0.44	No. of SPL	12
	Std. Dev.	0.12	CI	90
	CI Lower	0.38		
	CI Upper	0.50		
Pharmacotherapy (T2)	Mean	0.34	No. of SPL	12
	Std. Dev.	0.12	CI	90
	CI Lower	0.28		
	CI Upper	0.40		
Sound Therapy (T3)	Mean	0.19	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.15		
	CI Upper	0.23		
Surgery (T4)	Mean	0.03	No. of SPL	12
	Std. Dev.	0.02	CI	90
	CI Lower	0.02		
	CI Upper	0.04		

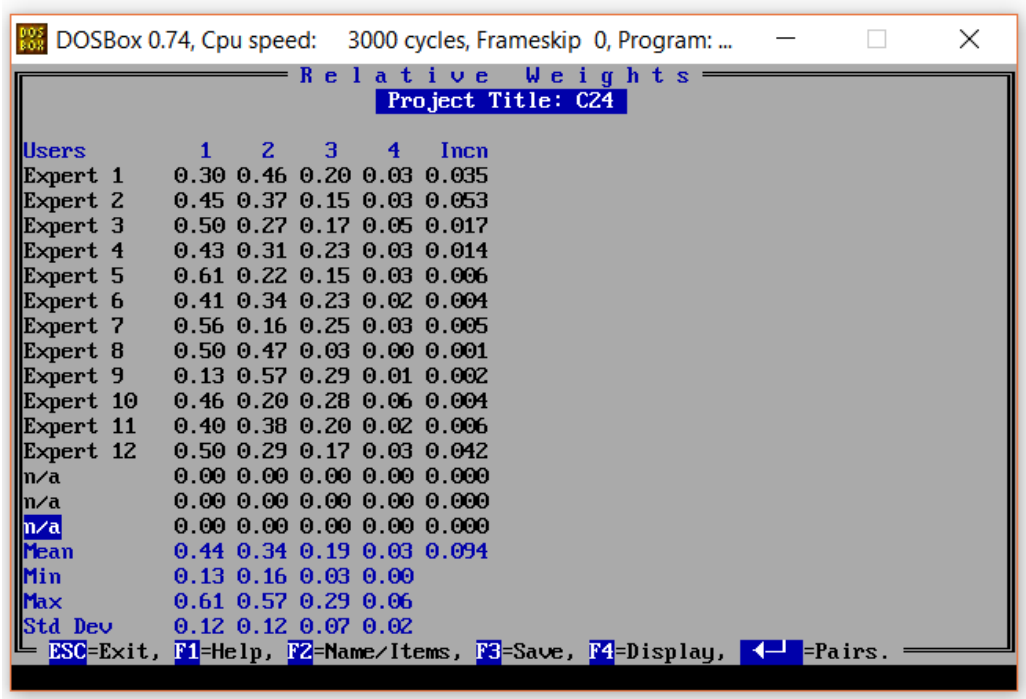


Figure 51: PCM Data Analysis Results with Respect to C24

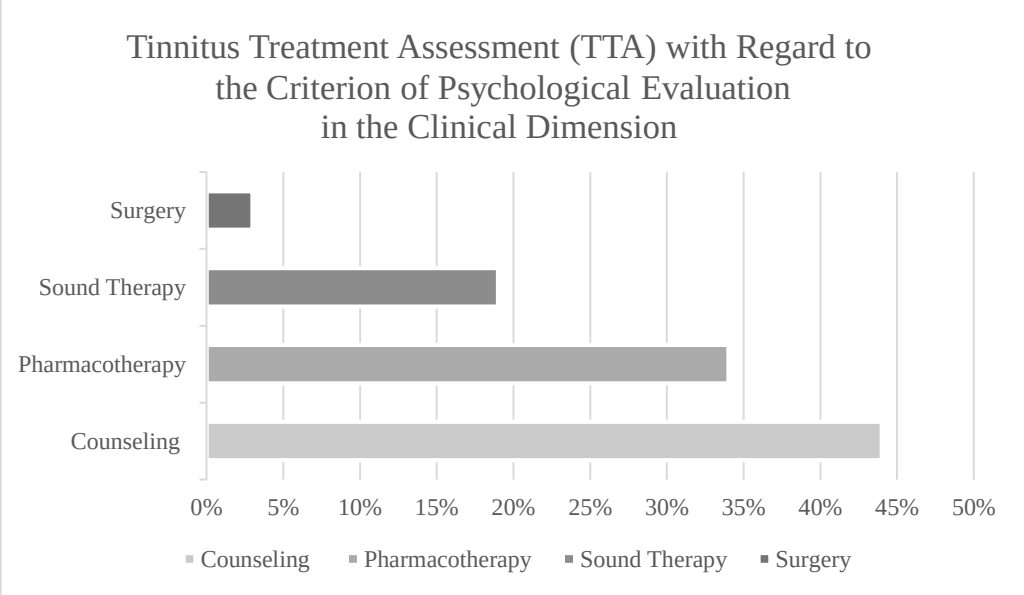


Figure 52: TTA with Respect to the Criterion of Psychological Evaluation (C24)

Table 30: Relative Ranking Values of the Alternatives with Respect to the Criterion of Chronic Tinnitus (C31)

Chronic Tinnitus (C31)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.47	0.27	0.22	0.03	0.022
Expert 2	0.52	0.14	0.30	0.04	0.014
Expert 3	0.62	0.14	0.19	0.05	0.039
Expert 4	0.35	0.39	0.23	0.03	0.014
Expert 5	0.58	0.14	0.25	0.03	0.003
Expert 6	0.41	0.14	0.43	0.02	0.042
Expert 7	0.49	0.30	0.18	0.03	0.010
Expert 8	0.49	0.43	0.05	0.04	0.000
Expert 9	0.25	0.38	0.34	0.03	0.002
Expert 10	0.50	0.15	0.29	0.05	0.015
Expert 11	0.39	0.30	0.27	0.03	0.013
Expert 12	0.56	0.22	0.19	0.03	0.046
Mean	0.47	0.25	0.24	0.04	
Minimum	0.25	0.14	0.05	0.02	
Maximum	0.62	0.43	0.43	0.06	
Standard Deviation	0.10	0.11	0.09	0.01	
Disagreement					0.09

Assessment of Chronic Tinnitus Criterion-Alternatives				
Counseling (T1)	Mean	0.47	No. of SPL	12
	Std. Dev.	0.1	CI	90
	CI Lower	0.42		
	CI Upper	0.52		
Pharmacotherapy (T2)	Mean	0.25	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.19		
	CI Upper	0.31		
Sound Therapy (T3)	Mean	0.24	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.19		
	CI Upper	0.29		
Surgery (T4)	Mean	0.04	No. of SPL	12
	Std. Dev.	0.01	CI	90
	CI Lower	0.03		
	CI Upper	0.05		

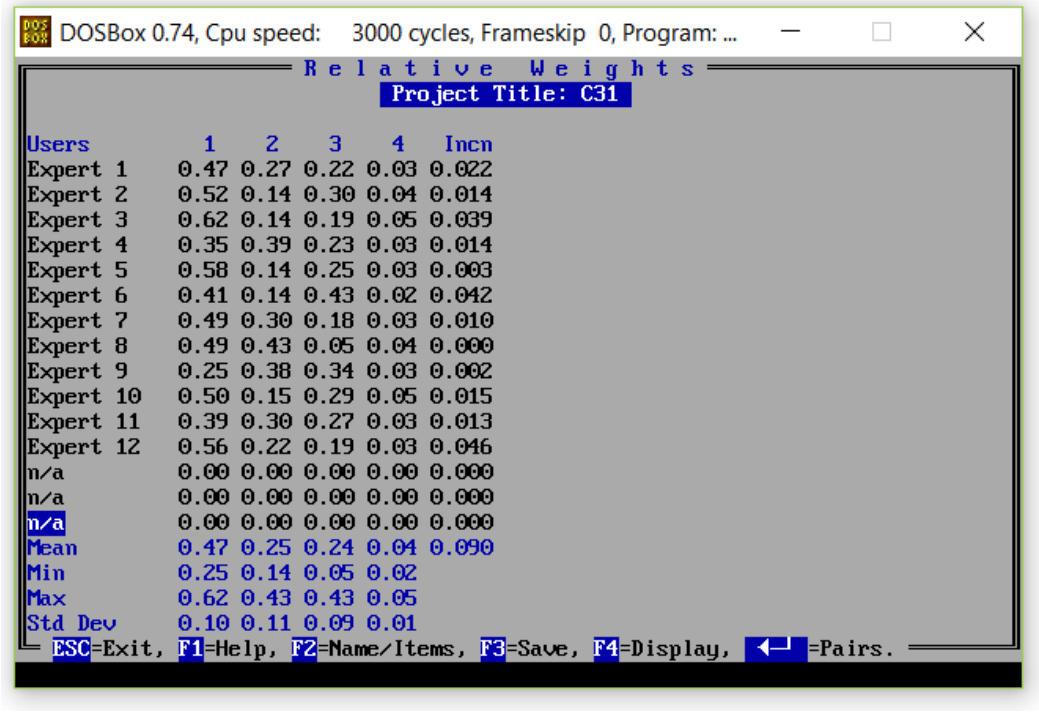


Figure 53: PCM Data Analysis Results with Respect to C31

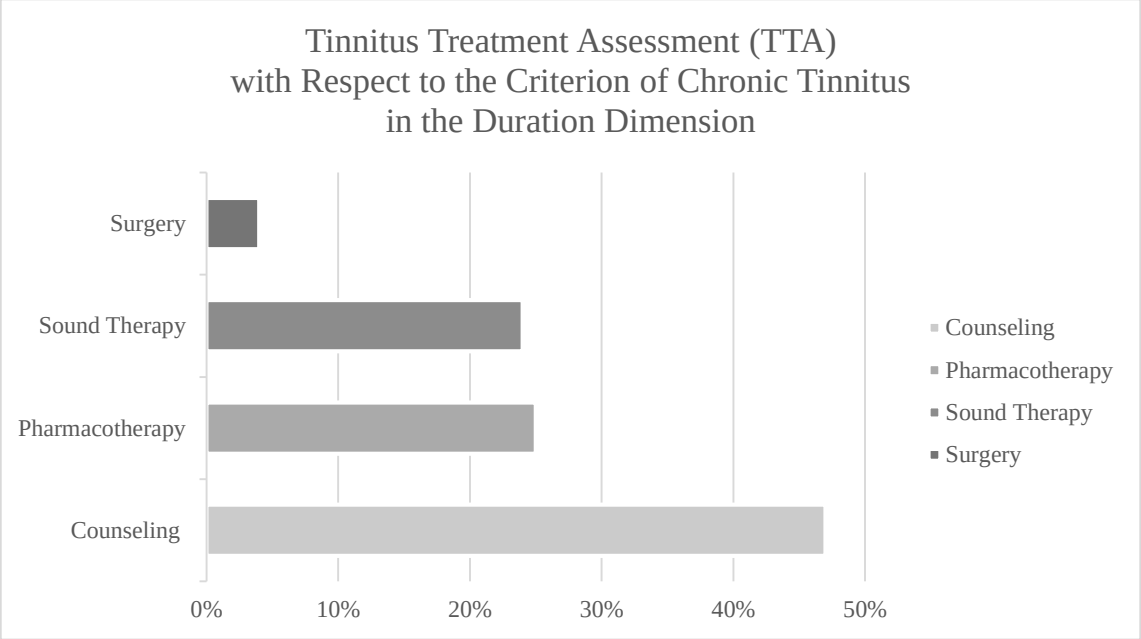


Figure 54: TTA with Respect to the Criterion of Chronic Tinnitus (C31)

Table 31: Relative Ranking Values of the Alternatives with Respect to the Criterion of Acute Tinnitus (C32)

Acute Tinnitus (C32)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.23	0.52	0.22	0.03	0.042
Expert 2	0.56	0.19	0.22	0.03	0.046
Expert 3	0.44	0.31	0.22	0.03	0.047
Expert 4	0.43	0.44	0.09	0.04	0.048
Expert 5	0.47	0.39	0.10	0.04	0.014
Expert 6	0.20	0.67	0.09	0.04	0.041
Expert 7	0.63	0.08	0.26	0.03	0.002
Expert 8	0.41	0.58	0.01	0.00	0.014
Expert 9	0.20	0.39	0.36	0.05	0.019
Expert 10	0.28	0.54	0.16	0.02	0.015
Expert 11	0.39	0.27	0.30	0.03	0.013
Expert 12	0.35	0.53	0.08	0.04	0.013
Mean	0.38	0.41	0.18	0.03	
Minimum	0.20	0.08	0.01	0.0	
Maximum	0.63	0.67	0.36	0.05	
Standard Deviation	0.14	0.17	0.10	0.01	
Disagreement					0.12

Assessment of Acute Tinnitus Criterion-Alternatives				
Counseling (T1)	Mean	0.38	No. of SPL	12
	Std. Dev.	0.14	CI	90
	CI Lower	0.31		
	CI Upper	0.45		
Pharmacotherapy (T2)	Mean	0.41	No. of SPL	12
	Std. Dev.	0.17	CI	90
	CI Lower	0.32		
	CI Upper	0.50		
Sound Therapy (T3)	Mean	0.18	No. of SPL	12
	Std. Dev.	0.10	CI	90
	CI Lower	0.13		
	CI Upper	0.23		
Surgery (T4)	Mean	0.03	No. of SPL	12
	Std. Dev.	0.01	CI	90
	CI Lower	0.02		
	CI Upper	0.04		

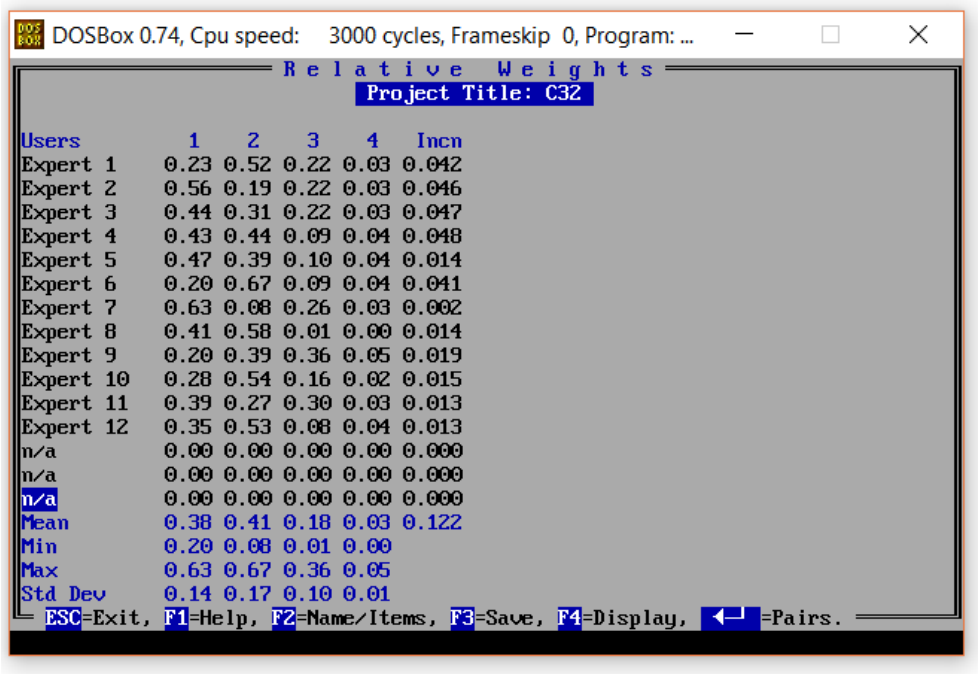


Figure 55: PCM Data Analysis Results with Respect to C32

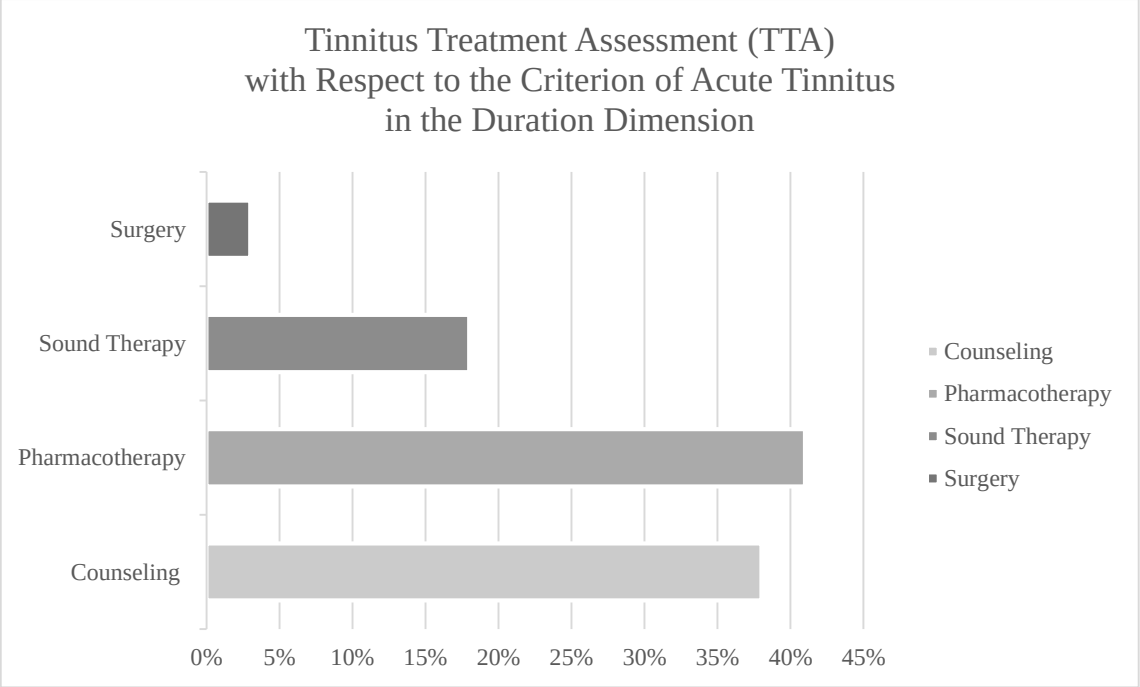


Figure 56: TTA with Respect to the Criterion of Acute Tinnitus (C32)

Table 32: Relative Ranking Values of the Alternatives with Respect to the Criterion of Treatment Effectiveness (C41)

Treatment Effectiveness (C41)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0. 22	0.45	0.29	0.04	0.022
Expert 2	0.43	0.14	0.36	0.07	0.052
Expert 3	0.53	0.14	0.25	0.08	0.069
Expert 4	0.39	0.26	0.32	0.04	0.008
Expert 5	0.51	0.27	0.18	0.04	0.015
Expert 6	0.37	0.35	0.22	0.05	0.017
Expert 7	0.49	0.18	0.30	0.03	0.010
Expert 8	0.13	0.17	0.21	0.49	0.005
Expert 9	0.28	0.37	0.31	0.04	0.004
Expert 10	0.43	0.14	0.30	0.13	0.015
Expert 11	0.39	0.20	0.29	0.12	0.004
Expert 12	0.43	0.35	0.17	0.04	0.004
Mean	0.38	0.25	0.27	0.10	
Minimum	0.13	0.14	0.17	0.03	
Maximum	0.53	0.45	0.36	0.49	
Standard Deviation	0.12	0.11	0.06	0.13	
Disagreement					0.10

Assessment of Treatment Effectiveness Criterion-Alternatives				
Counseling (T1)	Mean	0.38	No. of SPL	12
	Std. Dev.	0.12	CI	90
	CI Lower	0.32		
	CI Upper	0.44		
Pharmacotherapy (T2)	Mean	0.25	No. of SPL	12
	Std. Dev.	0.11	CI	90
	CI Lower	0.19		
	CI Upper	0.31		
Sound Therapy (T3)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.06	CI	90
	CI Lower	0.24		
	CI Upper	0.30		
Surgery (T4)	Mean	0.10	No. of SPL	12
	Std. Dev.	0.13	CI	90
	CI Lower	0.03		
	CI Upper	0.17		

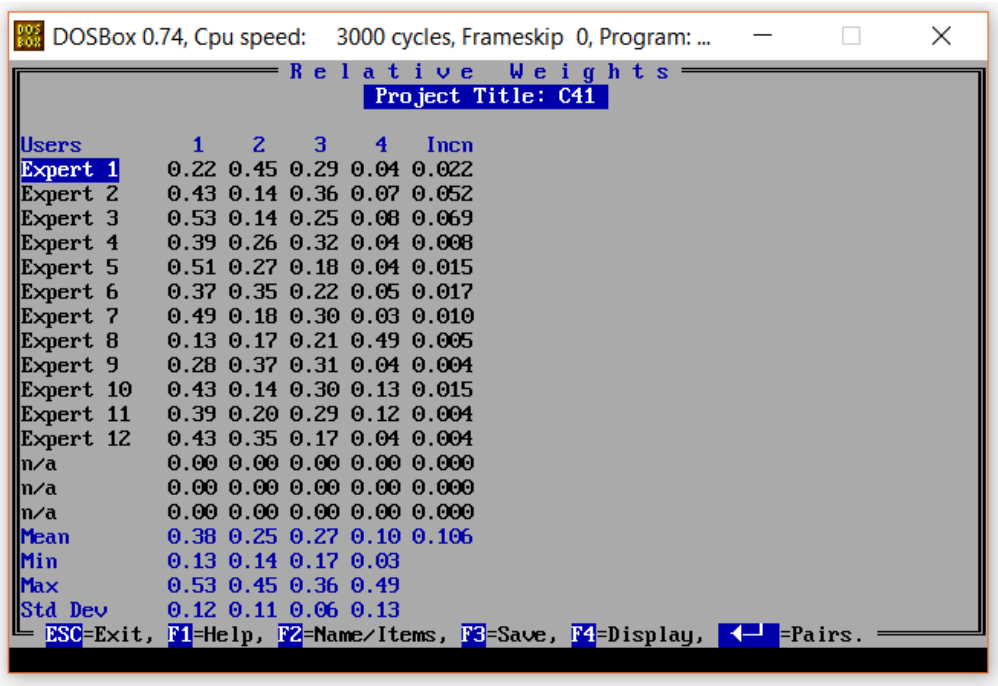


Figure 57: PCM Data Analysis Results with Respect to C41

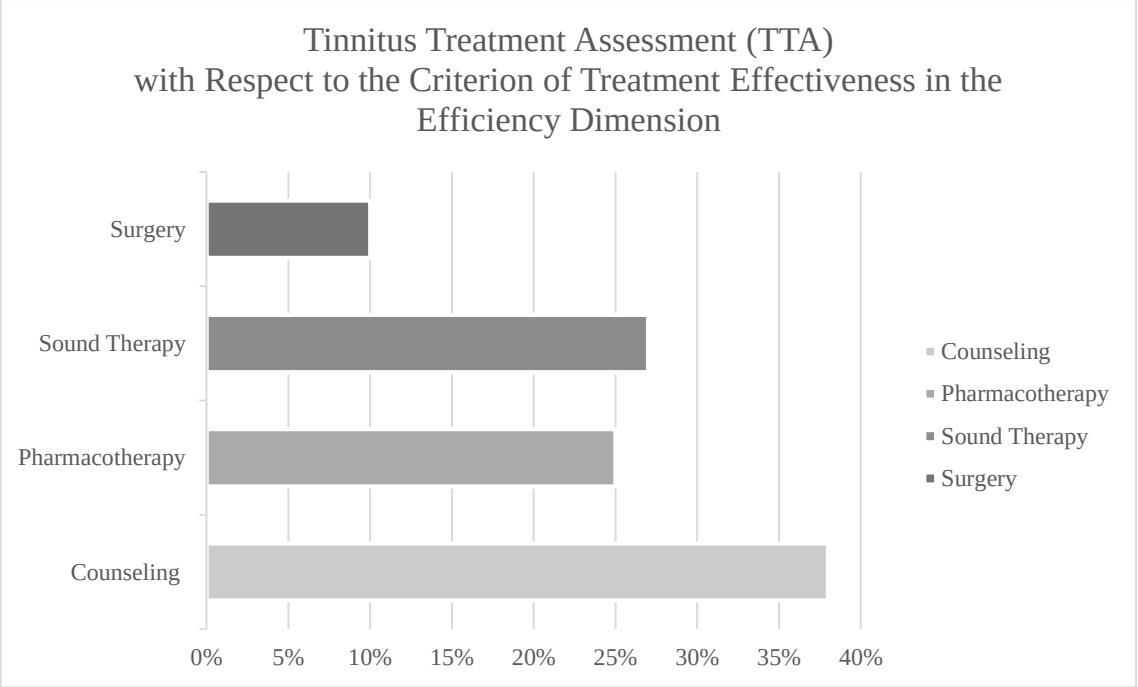


Figure 58: TTA with Respect to the Criterion of Treatment Effectiveness (C41)

Table 33: Relative Ranking Values of the Alternatives with Respect to the Criterion of Treatment Safety (C42)

Treatment Safety (C42)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0. 42	0.12	0.42	0.04	0.009
Expert 2	0.44	0.12	0.36	0.08	0.022
Expert 3	0.51	0.08	0.30	0.11	0.014
Expert 4	0.54	0.13	0.29	0.04	0.012
Expert 5	0.53	0.12	0.32	0.04	0.011
Expert 6	0.55	0.08	0.34	0.03	0.017
Expert 7	0.84	0.04	0.09	0.03	0.000
Expert 8	0.57	0.31	0.09	0.03	0.027
Expert 9	0.41	0.29	0.27	0.03	0.000
Expert 10	0.57	0.10	0.27	0.06	0.021
Expert 11	0.41	0.19	0.36	0.03	0.017
Expert 12	0.52	0.23	0.22	0.03	0.042
Mean	0.53	0.15	0.28	0.05	
Minimum	0.41	0.04	0.09	0.03	
Maximum	0.84	0.31	0.42	0.11	
Standard Deviation	0.12	0.08	0.10	0.03	
Disagreement					0.08

Assessment of Treatment Safety Criterion-Alternatives				
Counseling (T1)	Mean	0.53	No. of SPL	12
	Std. Dev.	0.12	CI	90
	CI Lower	0.47		
	CI Upper	0.59		
Pharmacotherapy (T2)	Mean	0.15	No. of SPL	12
	Std. Dev.	0.08	CI	90
	CI Lower	0.11		
	CI Upper	0.19		
Sound Therapy (T3)	Mean	0.28	No. of SPL	12
	Std. Dev.	0.10	CI	90
	CI Lower	0.23		
	CI Upper	0.33		
Surgery (T4)	Mean	0.05	No. of SPL	12
	Std. Dev.	0.03	CI	90
	CI Lower	0.03		
	CI Upper	0.07		

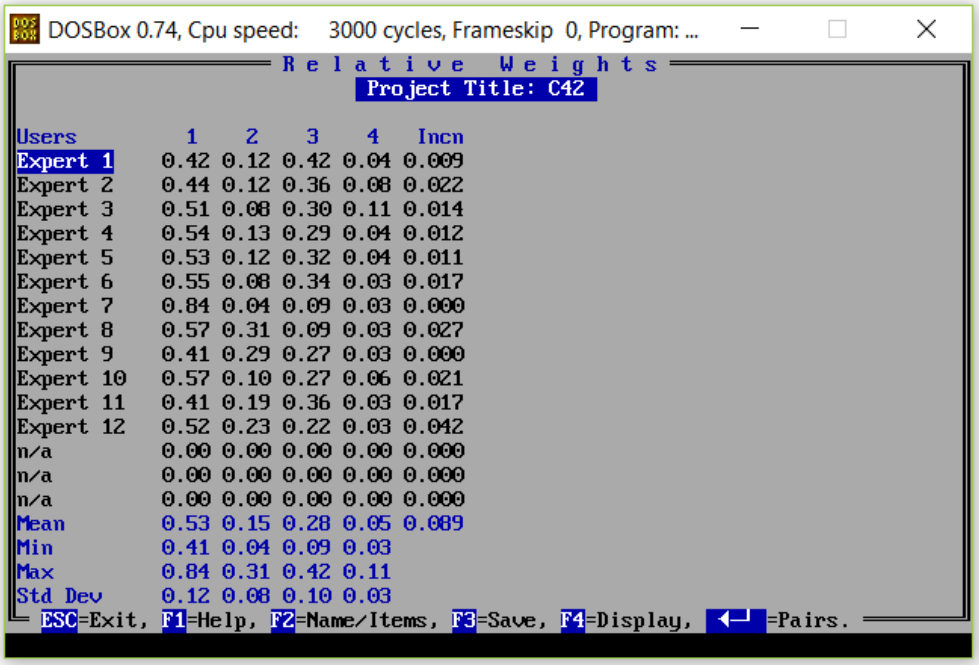


Figure 59: PCM Data Analysis Results with Respect to C42

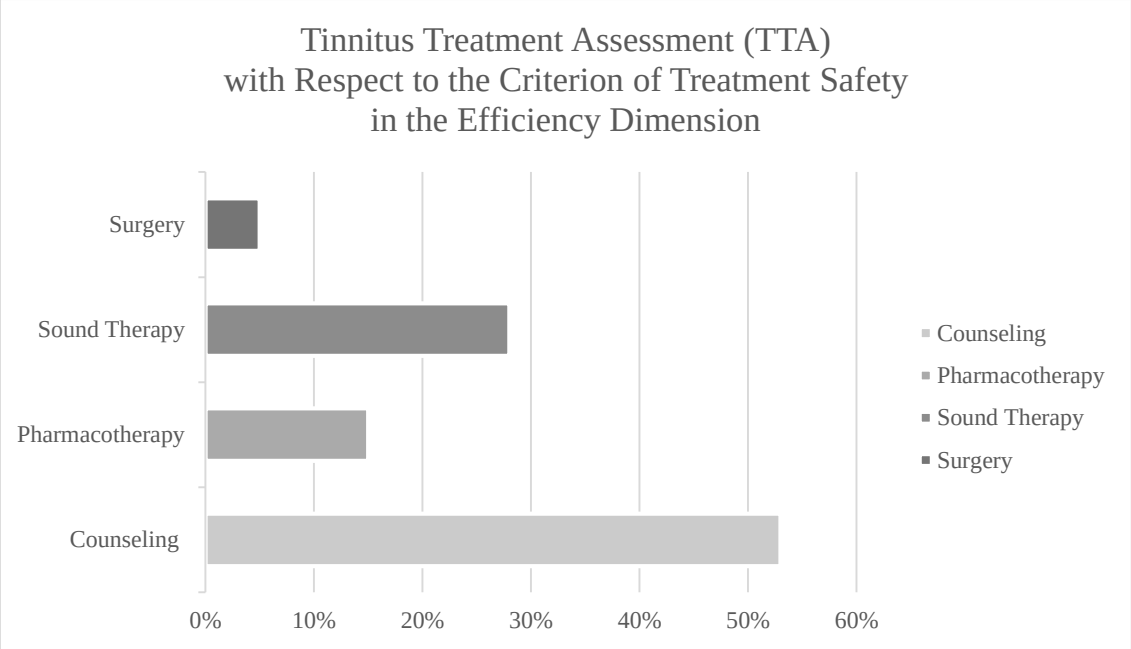


Figure 60: TTA with Respect to the Criterion of Treatment Safety (C42)

Table 34: Relative Ranking Values of the Alternatives with Respect to the Criterion of Treatment Cost (C43)

Treatment Cost (C43)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.43	0.38	0.12	0.07	0.058
Expert 2	0.57	0.31	0.07	0.05	0.013
Expert 3	0.63	0.16	0.13	0.09	0.014
Expert 4	0.55	0.26	0.13	0.06	0.002
Expert 5	0.76	0.17	0.05	0.01	0.031
Expert 6	0.43	0.34	0.19	0.03	0.027
Expert 7	0.47	0.288	0.19	0.06	0.003
Expert 8	0.49	0.46	0.02	0.02	0.003
Expert 9	0.33	0.34	0.17	0.16	0.015
Expert 10	0.67	0.12	0.16	0.05	0.029
Expert 11	0.39	0.30	0.27	0.03	0.013
Expert 12	0.58	0.23	0.15	0.04	0.029
Mean	0.53	0.28	0.14	0.06	
Minimum	0.33	0.12	0.02	0.01	
Maximum	0.76	0.46	0.27	0.16	
Standard Deviation	0.13	0.10	0.07	0.04	
Disagreement					0.08

Assessment of Treatment Cost Criterion-Alternatives				
Counseling (T1)	Mean	0.53	No. of SPL	12
	Std. Dev.	0.13	CI	90
	CI Lower	0.46		
	CI Upper	0.60		
Pharmacotherapy (T2)	Mean	0.28	No. of SPL	12
	Std. Dev.	0.10	CI	90
	CI Lower	0.23		
	CI Upper	0.33		
Sound Therapy (T3)	Mean	0.14	No. of SPL	12
	Std. Dev.	0.07	CI	90
	CI Lower	0.10		
	CI Upper	0.18		
Surgery (T4)	Mean	0.06	No. of SPL	12
	Std. Dev.	0.04	CI	90
	CI Lower	0.04		
	CI Upper	0.08		

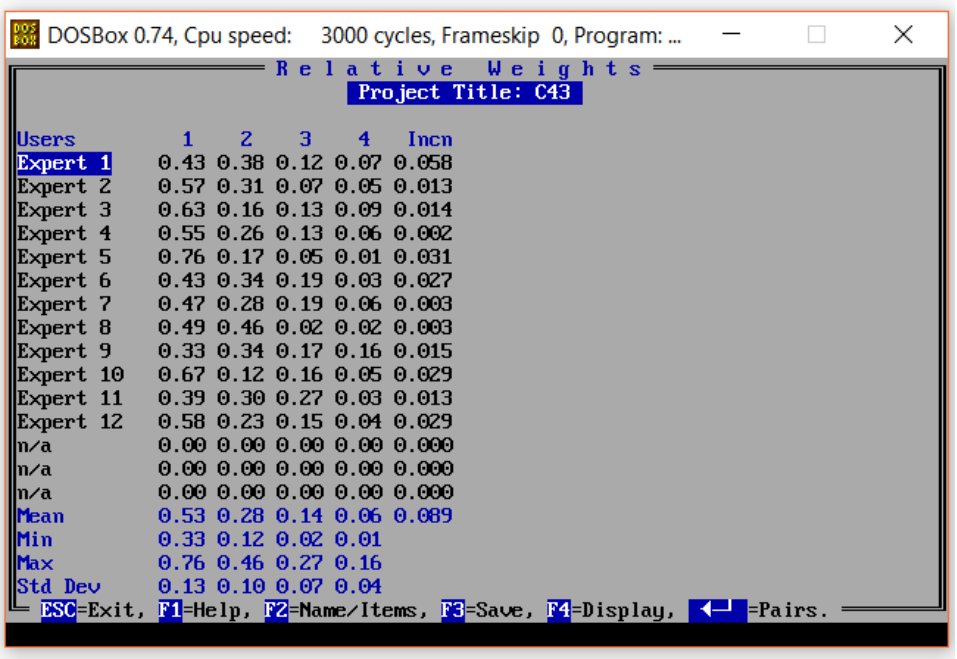


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Figure 61: PCM Data Analysis Results with Respect to C43

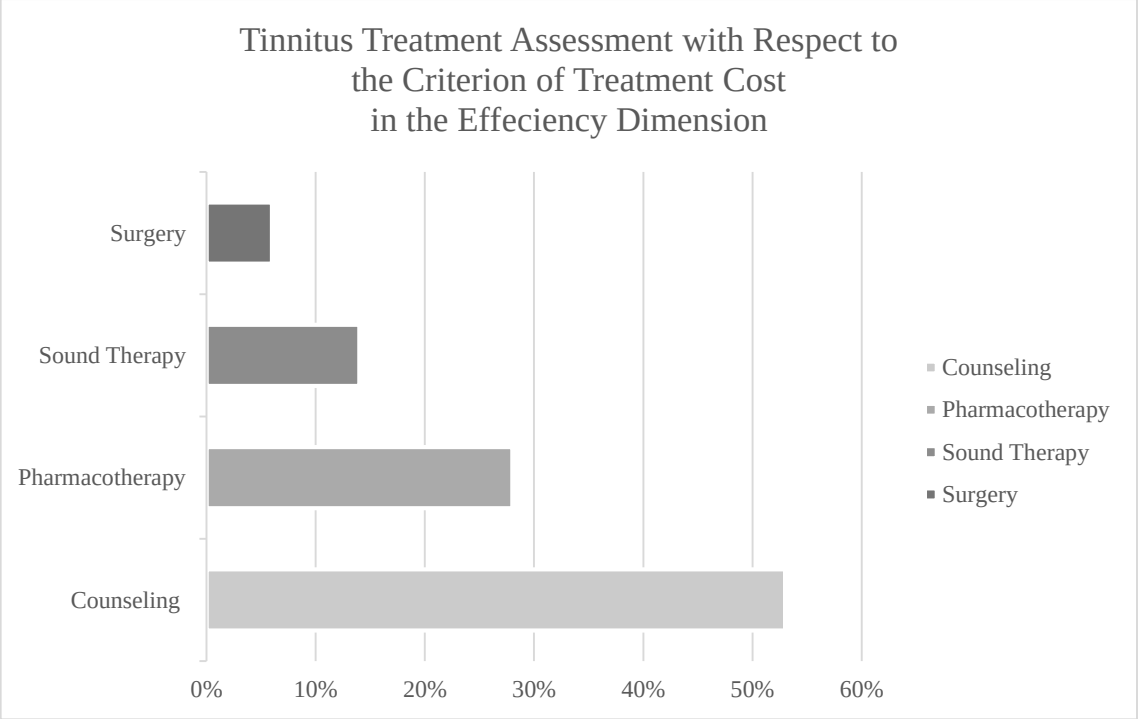

Figure 62: TTA with Respect to the Criterion of Treatment Cost (C43)

Table 35: Relative Ranking Values of the Alternatives with Respect to the Criterion of Treatment Compliance (C44)

Treatment Compliance (C44)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	0.23	0.56	0.15	0.06	0.029
Expert 2	0.53	0.16	0.27	0.04	0.015
Expert 3	0.41	0.24	0.21	0.14	0.083
Expert 4	0.42	0.16	0.31	0.11	0.032
Expert 5	0.53	0.27	0.16	0.04	0.015
Expert 6	0.46	0.15	0.34	0.05	0.012
Expert 7	0.49	0.30	0.18	0.03	0.010
Expert 8	0.37	0.52	0.04	0.07	0.001
Expert 9	0.39	0.31	0.26	0.04	0.000
Expert 10	0.52	0.14	0.30	0.04	0.014
Expert 11	0.39	0.30	0.27	0.03	0.013
Expert 12	0.51	0.19	0.27	0.03	0.034
Mean	0.44	0.27	0.23	0.06	
Minimum	0.23	0.14	0.04	0.03	
Maximum	0.53	0.56	0.34	0.14	
Standard Deviation	0.09	0.14	0.09	0.03	
Disagreement					0.09

Assessment of Treatment Compliance Criterion-Alternatives				
Counseling (T1)	Mean	0.44	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.39		
	CI Upper	0.49		
Pharmacotherapy (T2)	Mean	0.27	No. of SPL	12
	Std. Dev.	0.14	CI	90
	CI Lower	0.20		
	CI Upper	0.34		
Sound Therapy (T3)	Mean	0.23	No. of SPL	12
	Std. Dev.	0.09	CI	90
	CI Lower	0.18		
	CI Upper	0.28		
Surgery (T4)	Mean	0.06	No. of SPL	12
	Std. Dev.	0.03	CI	90
	CI Lower	0.04		
	CI Upper	0.08		

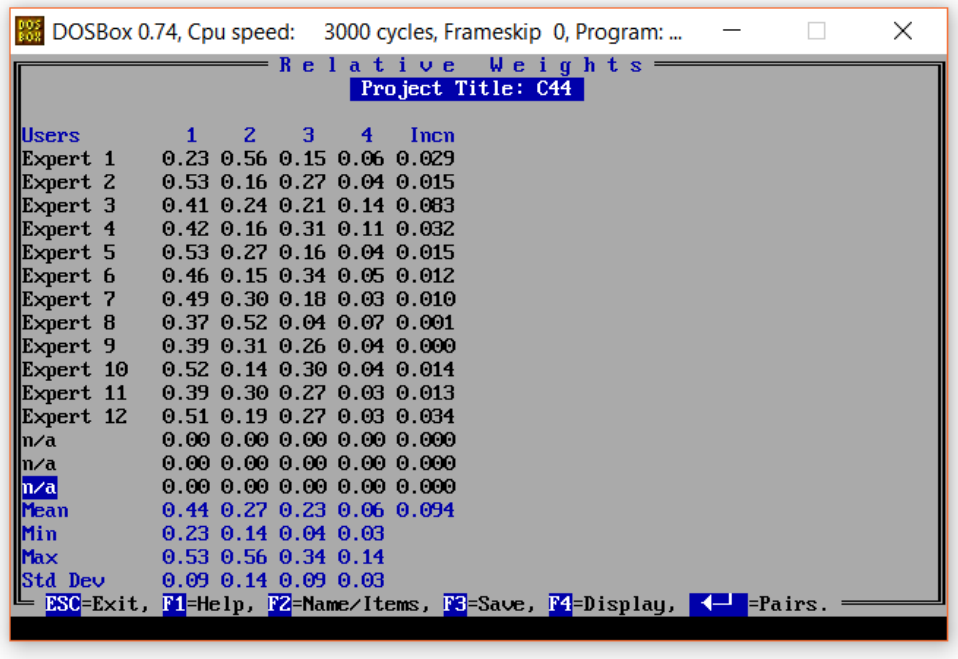

Figure 63: PCM Data Analysis Results with Respect to C44

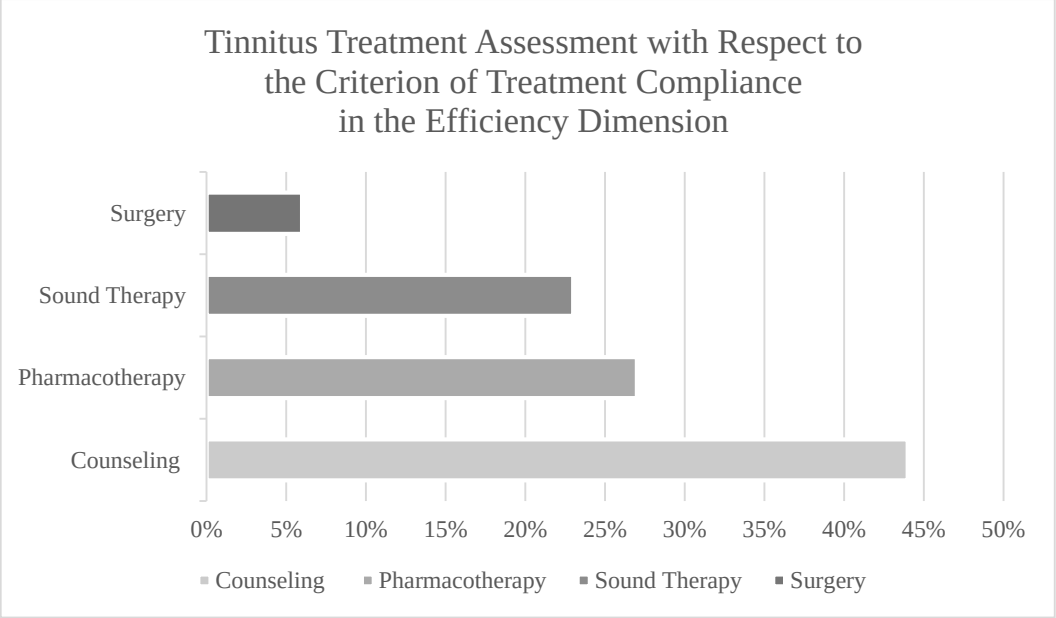

Figure 64: TTA with Respect to the Criterion of Treatment Compliance (C44)

To calculate the final treatment values (TV_n) with a specific description, two equations (Equations 2 and 3) are given in Chapter 4. These main formulae are recapitulated as follows:

$$TV_{dn} = \sum_{d=1}^{D} . \sum_{k=1}^{C_d} (y_{dk})(Z_{dkn})$$

$$TV_n = \sum_{d=1}^{D} (x_d)(TV_{dn})$$

The final treatment values (TV_n, where, n = 1, 2, 3 and 4) with respect to the four alternative tinnitus treatments (or T1, T2, T3 and T4) are illustrated in Table 36. Based on the final TVs, ranging from 0 to 100, which total the constant sum of 100, the most outstanding tinnitus treatment is T1 (or counseling) with a top-ranked treatment value of 45. In the second group, T3 (or sound therapy) is almost equivalent to T2 (or pharmacotherapy) with a gap score of 2 out of 100. The bottom-ranked alternative treatment is T4 (or surgery) with the meager

treatment value of 5. The relative evaluation presents the ranking and proportion of the priorities of the four alternatives, as shown in Table 37. Furthermore, the final treatment values are compared to the initial tinnitus treatment judgments, as illustrated in Figure 66, and the substantial gaps between the TV_n and the $S1_n$ (or initial treatment judgment values) are analyzed in Figures 65, 66, and 67.

Table 36: Treatment Values for the Four Candidate Tinnitus Treatments

Decision Elements	**Counseling (*T1*)**	**Pharmacotherapy (*T2*)**	**Sound Therapy (*T3*)**	**Surgery (*T4*)**
Diagnostic Dimension ($x_1 = 0.215$)	44.0	25.3	24.5	6.2
Clinical Dimension ($x_2 = 0.400$)	45.1	27.0	24.1	3.9
Duration Dimension ($x_3 = 0.215$)	45.1	28.3	22.8	3.8
Efficiency Dimension ($x_4 = 0.170$)	45.1	23.5	24.5	7.3
Treatment Value (*TV*) $TV_n = \sum_{d=1}^{D} (x_d)(TV_{dn})$	45	26	24	5

Table 37: Relative Ranking Values of the Four Alternative Tinnitus Treatments

Ranking	**Tinnitus Treatment**	**Treatment Value**	**Relative Evaluation**
1	T1: Counseling	45	100%
2	T2: Pharmacotherapy	26	58%
3	T3: Sound Therapy	24	53%
4	T4: Surgery	5	11%

Table 38: Relative Ranking Values of the Four Alternatives with Respect to Initial Judgments ($S1_n$)

Initial Judgment (S1)	**Counseling (T1)**	**Pharmacotherapy (T2)**	**Sound Therapy (T3)**	**Surgery (T4)**	**Inconsistency**
Expert 1	32	26	39	04	0.008
Expert 2	48	16	28	07	0.041
Expert 3	41	29	27	03	0.044
Expert 4	43	35	16	07	0.013
Expert 5	75	14	09	01	0.049
Expert 6	31	08	57	04	0.017
Expert 7	56	26	12	06	0.001
Expert 8	51	40	04	05	0.031
Expert 9	28	37	31	04	0.004
Expert 10	55	15	26	05	0.014
Expert 11	46	19	32	03	0.039
Expert 12	44	32	19	04	0.004
Mean	46	25	25	04	
Minimum	28	08	04	01	
Maximum	75	40	57	07	
Standard Deviation	13	10	14	02	
Disagreement					0.11

Assessment of Initial Judgment (S1)-Alternatives				
Counseling (T1)	Mean	46	No. of SPL	12
	Std. Dev.	13	CI	90
	CI Lower	39		
	CI Upper	53		
Pharmacotherapy (T2)	Mean	25	No. of SPL	12
	Std. Dev.	10	CI	90
	CI Lower	20		
	CI Upper	30		
Sound Therapy (T3)	Mean	25	No. of SPL	12
	Std. Dev.	14	CI	90
	CI Lower	18		
	CI Upper	32		
Surgery (T4)	Mean	4	No. of SPL	12
	Std. Dev.	2	CI	90
	CI Lower	3		
	CI Upper	5		

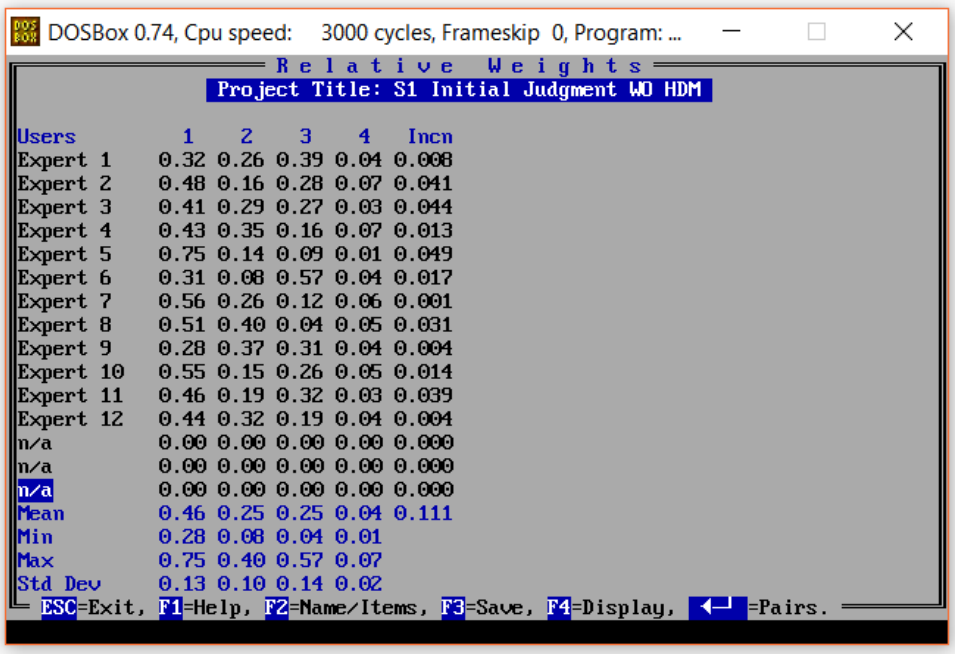

Figure 65: PCM Data Analysis with Respect to Initial Judgments ($S1_n$) without a Medical Decision Model

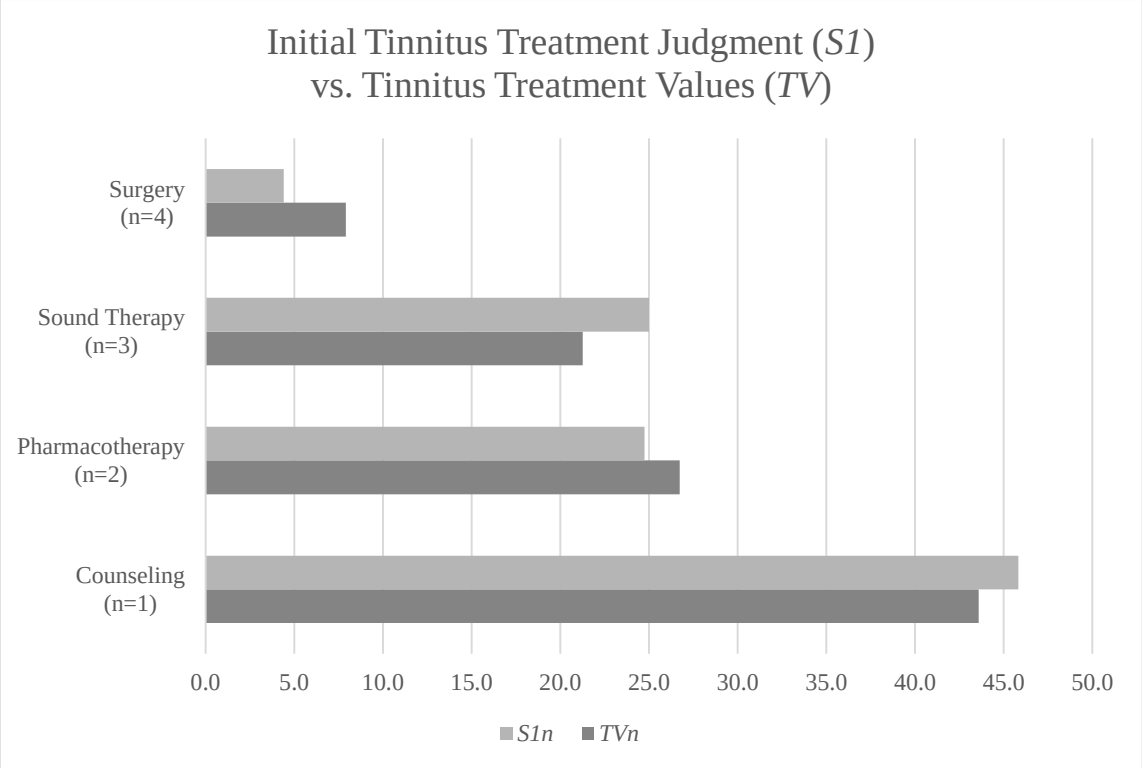

Figure 66: Treatment Values (TV_n) Comparisons with Initial Tinnitus Treatment Judgments ($S1_n$)

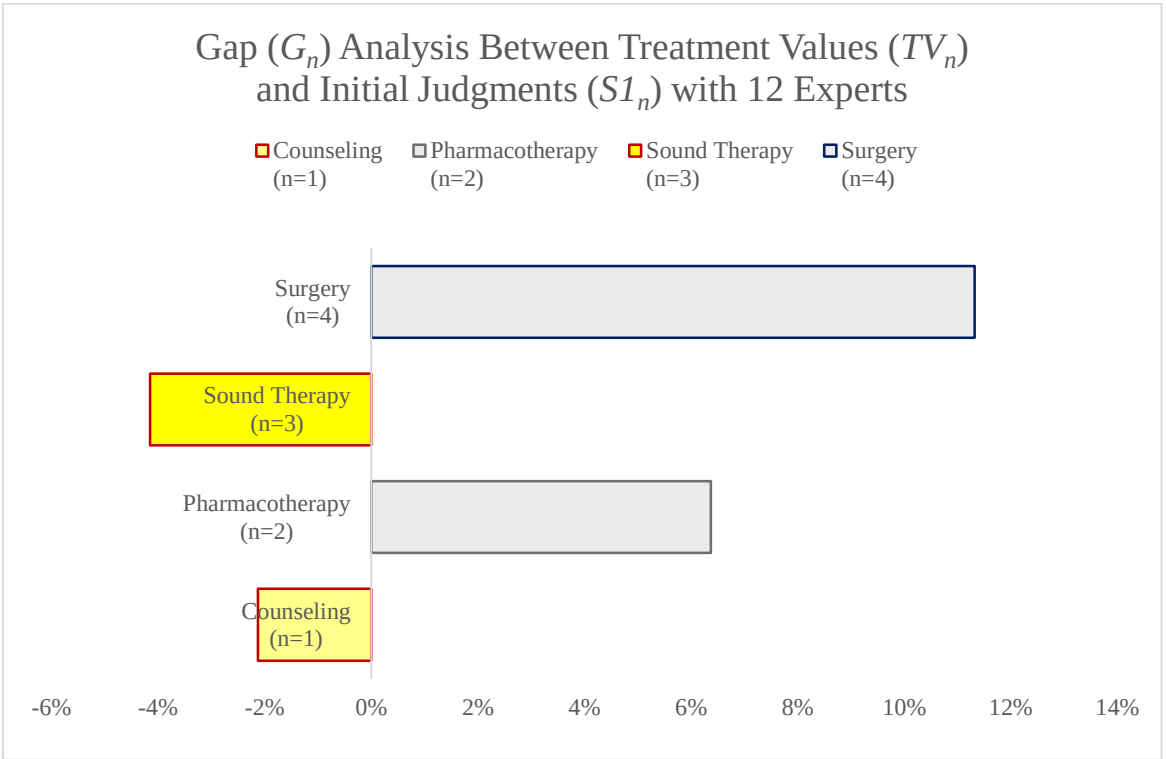

Figure 67: Gap Analysis between the Initial Treatment Judgments and the Final TTA with Treatment Values

Chapter 8

Research Assumptions and Limitations

8.1 Research Assumptions

The objective of this research pertains to the multi-criteria decision analysis for tinnitus treatment assessment using consensus-based expert judgments. In particular, tinnitus is a complex disorder with no definite cure for most chronic cases. Furthermore, this research is an application case study with a hierarchical decision model (HDM) and popular existing theories. The specific assumptions are illustrated in Table 39.

Table 39: Specific Research Assumptions

Subjects	Specific Assumptions
The Panel of Experts	1. Qualified Knowledge of Experts: Assumed that Korea's decision makers are otorhinolaryngologists with a specialty in tinnitus to attain the research objective of multi-dimensional tinnitus treatment assessment. 2. Population of Decision Makers: Assumed that there are available decision makers, who are 53 otorhinolaryngologists in Korea's otorhinolaryngological society of tinnitus study, pertains to the population of Korea's experts for the organization of an HDM panel. The sample size of twelve is 22.6% of this population of experts for tinnitus treatment assessment.

Subjects	Specific Assumptions
The Panel of Experts	3. Organized Panel of Experts: Assumed that a panel of experts must be qualified by their profiles with 15+ years of clinical experience as a medical doctor, 5+ years of specialty in tinnitus treatment to judge the multi-level decision elements: DCDE dimensions, 12 criteria and 4 alternatives in an HDM. 4. Availability of Data: Assumed that 1,080 ratio-scale pair-wise comparisons are available to quantify expert judgments with a twelve-member panel of experts, as detailed in Chapter 7. 5. Biased Input: Assumed that the multifarious clinical practices of each expert may affect the responses to research instrument.
An HDM / Multi-Criteria Decision Analysis	1. Hierarchical Structure: Assumed that the decision elements are placed in a series of distinctive multiple levels with classification without lateral connections. 2. HDM Framework: Assumed that the HDM framework with multilevel decision elements — DCDE dimensions and criteria associated with each dimension — be verified and confirmed by experts' reviews to compile the research instrument. 3. Integrative Relationships: Assumed that the alternatives may be assessed by the aggregative relative ranking values with respect to each criterion associated with each dimension under the mission.

8.2 Limitations

This study includes the limitations with respect to the HDM methodology and the relative risks to organize an expert panel. For tinnitus treatment assessment, otorhinolaryngologists specializing in tinnitus are qualified decision makers, as illustrated in the research assumptions. In this research, the iterations of evaluations by these decision makers are substantially critical issues for each expert in the panel. While the HDM is applicable to institute the multidimensional tinnitus treatment assessment based on expert judgments using ratio-scale pair-wise comparisons (RSPC), this multi-level decision analysis has engendered a considerable amount of debate to address the complexity, inconsistency and disagreement of each expert judgment. The unilateral decisions for each expert or each decision element cannot present the evaluation outcomes of alternative tinnitus treatments. For instance, the resulting rankings for a level of dimensions are not applicable to assess the alternatives without the evaluations with respect to the criteria. Furthermore, the weighting of each dimension affects the total treatment values. In particular, an excessive level of disagreement among experts' evaluations causes the decision makers to reassess their own expert judgments. At the same time, the inconsistent evaluation results of each expert induce the expert to constantly repeat the questionnaire. If any decision elements are modified in the verified or confirmed HDM, the revised research instrument has to be applied repeatedly for the entire panel of experts. The exponential increase of decision elements restricts the research instrument. Thus, in this research, the final HDM framework includes the most appropriate decision elements: the four DCDE dimensions, the twelve criteria and the four alternatives of tinnitus treatment without sub-criteria or factors.

Chapter 9

Conclusions

9.1 Research Outcomes

The initial and intermediate HDM frameworks and the verified HDM are the first outcome to comprehend the hierarchical structure and the wide range of decision elements: multiple dimensions, criteria associated with each dimension, and sub-criteria or factors to define each criterion. The five-step literature review process and conceptual literature framework could also be supplementary products in this research. The final multidimensional DCDE HDM was validated and confirmed by the consensus-based review of the panel of experts. In particular, the organization of the initial expert panel and a twelve-member panel of experts are the corner stone to institute the research instrument or judgment quantification instrument. The relative ranking outputs with respect to DCDE dimensions reveal the greater importance for the clinical dimension (D2) when compared with the three dimensions — diagnostic dimension (D1), duration dimension (D3) and efficiency dimension (D4). The initial judgments for the four candidate tinnitus treatments — (1) T1: counseling, (2) T2: pharmacotherapy, (3) T3: sound therapy and (4) T4: surgery — represent the gaps of the relative importance of each alternative treatment according to expert judgment quantification using ratio-scale pair-wise comparisons (RSPC). Based on the final treatment values (TV_n), the most outstanding tinnitus treatment is T1 (Counseling) with a top ranked treatment value. T3 (Sound therapy) and T2 (Pharmacotherapy) are almost equivalent. The bottom-ranked alternative treatment is T4 (Surgery) with the lowest treatment value (TV). The final treatment values and evaluation process are proven by the gap analysis with the initial tinnitus treatment judgments. T1 and T3 have a positive directionality, which means final treatment values (TV_n) for T1 and T3 are

greater than the initial judgments ($S1_n$), as illustrated in Figure 66. The negative directionality of T2 and T4 are shown in Figure 67. The case study produces the outcomes to assimilate the HDM relative ranking analysis, the research assumptions and limitations. The seven-phase HDM research process is applied to validate the research outcomes.

9.2 Research Contributions

9.2.1 Contribution to the Body of Knowledge

This research could benefit all-inclusive stakeholders for tinnitus management (TM) and tinnitus treatment assessment (TTA). The domestic or international otorhinolaryngological society of tinnitus enables the assimilation of this multi-dimensional TTA into a general medical decision model based on a hierarchical decision model (HDM) applied to a multi-criteria and multi-level decision analysis. The ameliorative research frameworks — initial and intermediate HDM (i-HDM) frameworks, and the final verified HDM (v-HDM) framework — can be comprehensively distributed. The seven-phase process is fundamental to institute a robust HDM-based TTA, as illustrated in Chapter 5. The definition of decision elements — the four DCDE dimensions D1 to D4, the twelve criteria C11 to C12, and the four candidate alternatives T1 to T4 — is essential to understand a medical decision model for TTA, as detailed in Chapter 6. The relative ranking values of alternatives with respect to each criterion in multiple DCDE dimensions recapitulate the classification of top, middle, and bottom criteria in the competitive consideration of the four DCDE dimensions based on treatment values (TV_n), as shown in Chapter 7.

9.2.2 Gap Analysis for the Identification of Research

To ascertain the gaps in tinnitus treatment assessment (TTA) in Korea's otorhinolaryngological case study, the multiple DCDE dimensions represent the biased existing research, as detailed in Chapter 2. The clinical evaluation dimension (D2) has a substantial role in the DCDE

dimensions for TTA in most research. Diagnostic (D1), duration (D3), and efficiency (D4) dimensions are involved to a greater or lesser extent; examples are D1 and D3, which are the second largest proportion; the rate values of D1 and D3 are about half the value of D2. D4 has the smallest relative ranking value in the DCDE model. Medical papers are focus on the one-dimensional (1D) clinical evaluation dimension (D2) and the combined two-dimensional (2D) studies: (1) Diagnostic and Clinical Evaluation (DC: D1 & D2) and (2) Clinical Evaluation and Efficiency (CE: D2 & D4). The papers classified into all-inclusive four DCDE dimensions (4D) and 3D TTA are the fewest in D2, D3 and D4, as detailed in Chapter 2. The four dimension (4D)-TTA papers do not pertain to the decision model-based research using multiple criteria associated with each dimension. Three categories — (1) tinnitus treatments, (2) multiple dimensions and (3) references for a hierarchical decision model (HDM) — are reviewed by the major international journals and certified full text of papers using over 665 databases of Stony Brook Library, *KISEP*, *KoreaMed* and *Google Scholar*.

9.2.3 Application of the HDM for an Interdisciplinary Multidimensional Tinnitus Treatment Assessment (TTA)

To attain the consensus-based HDM, the verification and validation of the intermediate HDM are iterated by the panel of experts. In the final HDM, a dimension of cohort of age, the associated criteria and the wide range of sub-criteria or factors are removed. In particular, the factors are used to define each criterion, as detailed in Chapter 6. Korea's otorhinolaryngologists' feedback on an HDM criterion engenders the appropriate revisions and institutes an interdisciplinary multidimensional tinnitus treatment assessment (TTA) model and the research instrument. For instance, the criterion of temporary tinnitus was amended by the criterion of acute tinnitus (C32) based on the expert review. The final HDM includes twelve criteria without sub-criteria or factors, as illustrated in Figure 30. The verified HDM is

applicable for a comprehensive TTA with the decision modeling, as detailed in Chapters 4 & 6.

Ratio-scale pair-wise expert judgments are distinctively quantified with respect to multi-level decision elements. The multi-level assessment will offer profound insight into comprehending the decision analysis for treatment assessment. To validate the expert judgments, the HDM guidelines for the inconsistency level and disagreement level will be applied. The level of inconsistency (LOI) pertains to a logical response to the research instrument based on the expert judgments. If the value of LOI is higher than 0.10, the coordinator will provide the analysis results to the appointed experts concurrently and re-apply the related research instrument to aggregate the expert judgment values. Analyzing the level of disagreement (LOD) is critical to validate the consensus among the experts rather than the consistency of an expert. The LOD denotes the gaps in the aggregated expert judgments. The LOD is the mean of inconsistency of judgment values from the multiple experts in the panel of experts. The criterion for LOD is less than the value of 0.10. The value of 0.10 of LOD denotes the 90% consensus among the multiple experts in the expert panel. To comprehend the rationale of disagreement, the coordinator may investigate the distinctive attributes of each expert judgment. If the initial judgments are not available to satisfy the consensus-based appraisal (or LOD), a second round of the research instrument may be applicable. In the modified Delphi technique method, the repetitions are applied to avoid substantial disagreement. The detailed analysis for LOI and LOD is illustrated in Chapter 6.

With respect to multiple DCDE dimensions, the different relative importance or weighting could be independent from the relative ranking values with respect to each criterion. For instance, the panel of experts determined the clinical dimension as the top-ranked dimension.

The diagnostic and duration dimensions hold second place. The lowest relative ranking value with respect to the four DCDE dimensions is the tinnitus treatment efficiency dimension (E) in fourth place, as illustrated in Figure 68. The relative ranking values of all DCDE dimensions are higher than 15% regarding the mission; these values indicate that each dimension is significant. In particular, the ranking value of 17% for surgery (T4) presents the eminently imperative alternative surgical treatment with respect to somatosounds (C12). The lowest value of 3% for surgery with respect to psychological evaluation (C24) and acute tinnitus (C32) is 0.176 times of this value of 17%. The value of 41% for T2 regarding C32 is 2.7 times higher than the value of 15% for T2 with respect to C42.

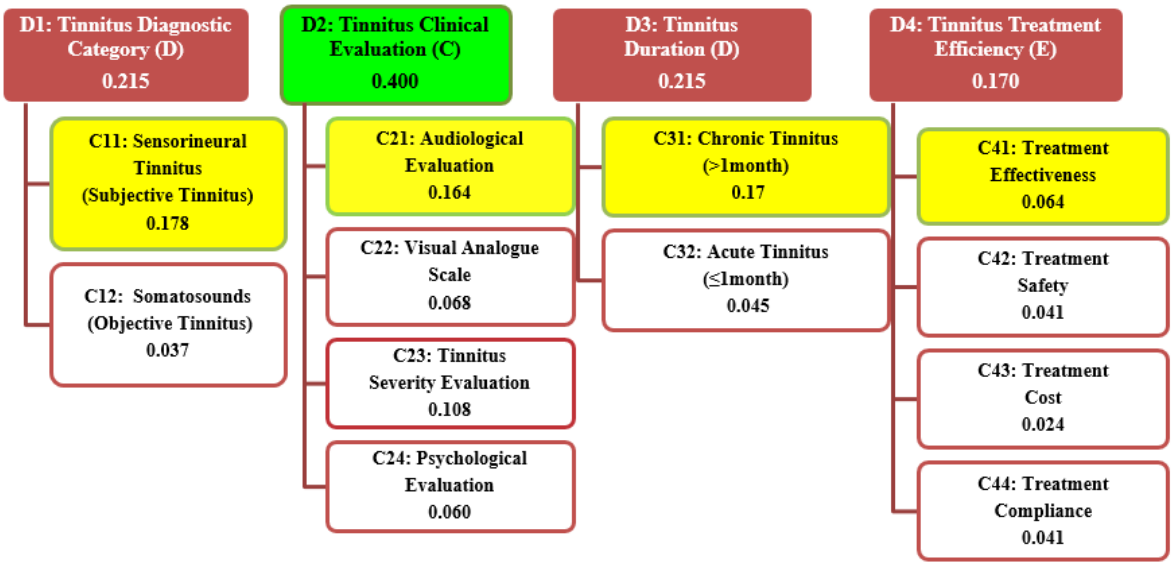

Figure 68: Contributions of All Decision Elements to the Mission

9.3 Future Research

This research is a multi-dimensional tinnitus treatment assessment to comprehend the 17 multi-level decision elements, and an HDM application based on 1,080 expert judgments. In particular, this multi-criteria decision analysis approach may foster all-inclusive treatment assessment and distribute the body of knowledge of the HDM framework, research instrument,

the Delphi consensus-based technique, ratio-scale pair-wise comparisons (RSPC), the synthesis of treatment values and the inconsistency and disagreement for competent data validation.

For the international expert judgments, a future panel of experts will include: more than twenty experts from different countries, which is 1.67 times more than the current panel of experts in Korea's otorhinolaryngology society of tinnitus. The research instrument and the final HDM will be compiled with these additional experts. To comply with the judgment qualification instrument and the competent data validation, the current 1,080 data of the ratio-scale pair-wise comparisons (RSPC) will expand by 2,880 data from the new panel of 32 experts for several years. If the new global experts provide feedback about new alternatives, criteria, dimensions and factors in an HDM, these decision elements will be refined and qualified based on the consensus-based review.

To reduce the value of LOD to less than 0.10 with respect to the two criteria, somatosounds (C12) and acute tinnitus (C32), further international expert judgments with a new expanded panel of experts and the iterations of existing evaluations will be compiled. The different desirability of T2 for C32 and T4 for C12 increases the LOD.

Further candidates for tinnitus treatment could comply with the revalidation process. If the HDM adds or deletes any decision elements — dimensions, criteria, and alternatives — all 1,080 expert judgments must be reevaluated. Thus, the change of the HDM will be contemplated with the international panel of experts. This treatment assessment research can also encourage new medical decision models for other otorhinolaryngological chronic diseases with the competent panel of experts.

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Appendices

A. Judgment Quantification Instrument (Expert Judgment Questionnaire for Tinnitus Treatment Assessment)

EXPERT JUDGMENT QUESTIONNAIRE
FOR TINNITUS TREATMENT ASSESSMENT

The objective of this research was the multiple dimensional assessment of tinnitus treatments with expert judgment. The study design was: a framework of decision modeling, pairwise comparison analysis, and tinnitus treatment values based on relative ranking appraisal. Please help us identify the most appealing features of tinnitus treatments, by following the instructions given to you in this questionnaire.

Please print and review the tabs/worksheets: (1) Questionnaire, (2) HDM Diagram, (3) Criteria & Factors

Number of Years of Professional Experience: ____Years (___Years for Tinnitus Treatment)_

Highest Degree Achieved (please circle o BS MS PhD MD Other_____

How do you rate yourself in your knowledge of tinnitus?

No Knowledge					**Very Knowledgeable**
0	**1**	**2**	**3**	**4**	**5**

The mission is to examine tinnitus treatments in view of multiple dimensions and criteria for the holistic assessment of tinnitus treatments with expert judgment.

Section 1: Pair-wise Comparison for Decision Making of Four Candidate Tinnitus Treatments
In this section you will determine the relative importance of four candidate tinnitus treatments below as they affect the overall tinnitus treatment values based on the relative ranking for South Korea.

A : Counseling

B : Pharmacotherapy

C : Sound Therapy

D : Surgery

Pair-wise Comparison Instructions: For each pair listed below, please:

1. Allocate a total of 100 points to reflect how many times a treatment is important in comparison to the other under consideration.

2. Reply the appropriate number to account for the relative importance between the two elements toward the vision under consideration by using the following score:

   50 = Two elements are equally important for the mission in your expert judgment than the second.

   67 = The first element is 2 times more important for the mission in your expert judgment than the second.

   75 = The first element is 3 times more important for the mission in your expert judgment than the second.

   80 = The first element is 4 times more important for the mission in your expert judgment than the second.

   83 = The first element is 5 times more important for the mission in your expert judgment than the second.

   90 = The first element is 10 times more important for the mission in your expert judgment than the second.

3. If you answer the left-side element, the embedded logic function can provide the value of right-side element. The manual inputs of all element values are available as well.

Example : If you think that counseling and pharmacotherapy are equally important, you would respond :

Counseling	50	vs.	50	Pharmacotherapy

If you think that counseling is 3 times more important than pharmacotherapy, you would respond :

Counseling	75	vs.	25	Pharmacotherapy

S1 PLEASE REPLY THE DESIRABLE NUMBER THAT RANGES FROM 0 TO 100.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

Section 2: Pair-wise Comparison for Decision Making of Multiple Dimensions
In this section you will determine the relative importance of multiple dimensions below as they affect the comprehensive assessment of tinnitus treatments for South Korea.

A : Tinnitus Diagnostic Categories

B : Tinnitus Clinical Evaluation

C : Tinnitus Duration

D : Tinnitus Treatment Efficiency

S2 PLEASE REPLY THE DESIRABLE NUMBER THAT RANGES FROM 0 TO 100.

Tinnitus Diagnostic Categories		vs.		Tinnitus Clinical Evaluation
Tinnitus Diagnostic Categories		vs.		Tinnitus Duration
Tinnitus Diagnostic Categories		vs.		Tinnitus Treatment Efficiency
Tinnitus Clinical Evaluation		vs.		Tinnitus Duration
Tinnitus Clinical Evaluation		vs.		Tinnitus Treatment Efficiency
Tinnitus Duration		vs.		Tinnitus Treatment Efficiency

Mission: Comprehensive assessment of Treatments for Tinnitus

PLEASE REPLY THE DESIRABLE NUMBER THAT RANGES FROM 0 TO 100.

D1 In view of the clinical dimension of tinnitus diagnostic categories to assess tinnitus treatments, please compare the relative importance of a criterion in each pair with the other one. Examples of criteria include sensorineural tinnitus (subjective tinnitus) and somatosounds (objective Tinnitus). To further understand each criterion refer to the description of criteria & factors. For example, a criterion of somatosounds (objective tinnitus) is composed of vascular tinnitus, muscle origin tinnitus, tinnitus due to patulous Eustachian tube, and etc.

Sensorineural Tinnitus (Subjective Tinnitus)		vs.		Somatosounds (Objective Tinnitus)

Tinnitus Diagnostic Categories

D2 In view of a dimension of tinnitus clinical evaluation to assess tinnitus treatments, please compare the relative importance of a criterion in each pair with the other one. Examples of criteria include audiological evaluation, visual analogue scale (VAS), tinnitus severity evaluation and psychological evaluation. To further understand each criterion refer to the description of criteria & factors. For example, a criterion of audiological evaluation is composed of factors such as audiometry & speech audiometry, minimum masking level, tinnitus matching and

Audiological Evaluation		vs.		Visual Analogue Scale
Audiological Evaluation		vs.		Tinnitus Severity Evaluation
Audiological Evaluation		vs.		Psychological Evaluation
Visual Analogue Scale		vs.		Tinnitus Severity Evaluation
Visual Analogue Scale		vs.		Psychological Evaluation
Tinnitus Severity Evaluation		vs.		Psychological Evaluation

A Dimension of Tinnitus Clinical Evaluation

D3 In view of a dimension of tinnitus duration to assess tinnitus treatments, please compare the following criteria Examples of criteria include chronic tinnitus (>1month) and acute tinnitus (≤1month) with temporary tinnitus.

Chronic Tinnitus (>1month)		vs.		Acute Tinnitus (≤1month)

A Dimension of Tinnitus Duration

D4 Considering the "Dimension of Tinnitus Treatment Efficiency" to assess tinnitus treatments, please compare the following criteria. Examples of criteria include "Treatment Effectiveness", "Treatment Safety", "Treatment Cost" and "Treatment Compliance".

Treatment Effectiveness		vs.		Treatment Safety
Treatment Effectiveness		vs.		Treatment Cost
Treatment Effectiveness		vs.		Treatment Compliance
Treatment Safety		vs.		Treatment Cost
Treatment Safety		vs.		Treatment Compliance
Treatment Cost		vs.		Treatment Compliance

A Dimension of Tinnitus Treatment Efficiency

Section 4 : Pair-wise Comparison for Decision Making of Four Alternatives of Tinnitus Treatments with respect to each Criterion

In this section you will determine the relative importance of four alternatives below with respect to twelve criteria.

Example : If you think that "Counseling" and "Surgery" are equally important with respect to a criterion of "Chronic Tinnitus", you would respond :

Counseling	50	vs.	50	Surgery

If you think that "Counseling" is 4 times more important than "Surgery" with respect to a criterion of "Tinnitus Treatment Safety", you would respond :

Counseling	80	vs.	20	Surgery

If you think that "Surgery" is 2 times important than "Counseling" with respect to a criterion of "Tinnitus Treatment Effectiveness", you would respond :

Counseling	33	vs.	67	Surgery

PLEASE REPLY THE DESIRABLE NUMBER THAT RANGES FROM 0 TO 100.

C1 Considering a "Criterion of Sensorineural Tinnitus (Subjective Tinnitus)" to assess tinnitus treatments, please compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C1: Criterion of Sensorineural Tinnitus (Subjective Tinnitus)

C2 Considering a "Criterion of Somatosounds (Objective Tinnitus)" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C2: Criterion of Somatosounds (Objective Tinnitus)

C3 Considering a "Criterion of Audiological Evaluation" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C3 : Criterion of Audiological Evaluation

C4 Considering a "Criterion of Visual Analogue Scale" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C4: Criterion of Visual Analogue Scale (VAS)

C5 Considering a "Criterion of Tinnitus Severity Evaluation" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C5: Criterion of Tinnitus Severity Evaluation

C6 Considering a "Criterion of Psychological Evaluation" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C6: Criterion of Psychological Evaluation

C7 Considering a "Criterion of Chronic Tinnitus" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C7: Criterion of Chronic Tinnitus

C8 Considering a "Criterion of Acute Tinnitus" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C8: Criterion of Acute Tinnitus

C9 Considering a "Criterion of Treatment Effectiveness" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C9: Criterion of Treatment Effectiveness

C10 Considering a "Criterion of Treatment Safety" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C10: Criterion of Treatment Safety

C11 Considering a "Criterion of Treatment Cost" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C11: Criterion of Treatment Cost

C12 Considering a "Criterion of Treatment Compliance" to assess tinnitus treatments compare the following alternatives: Counselling, Pharmacotherapy, Sound Therapy and Surgery.

Counseling		vs.		Pharmacotherapy
Counseling		vs.		Sound Therapy
Counseling		vs.		Surgery
Pharmacotherapy		vs.		Sound Therapy
Pharmacotherapy		vs.		Surgery
Sound Therapy		vs.		Surgery

C12: Criterion of Treatment Compliance

B. Multiple Criteria and Factors (Sub-Criteria) with Respect to the Multi-DCDE Dimensions