EVALUATION OF HONG KONG’S INDOOR AIR QUALITY MANAGEMENT PROGRAMME: CERTIFICATION SCHEME, OBJECTIVES, AND TECHNOLOGY

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February 27, 2014

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Interactive Qualifying Project Report completed in partial fulfillment
Of the Bachelor of Science degree at
Worcester Polytechnic Institute, Worcester, MA

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Date: February 27, 2014

Abstract

This study, sponsored by the Business Environment Council, investigated people's perceptions of indoor air quality (IAQ) in shopping malls certified under the Hong Kong IAQ Certification Scheme and uncertified Hong Kong shopping malls. Questionnaires were utilized to collect people's opinions and data were analyzed with statistical tests. Questionnaire results indicated no statistical difference between people's perception of IAQ in certified and uncertified malls. Questionnaire results may be an indication of malls not maintaining IAQ standards post-certification. An update of Hong Kong's IAQ Objectives was recommended after comparison with international IAQ guidelines. Summaries of some of the latest IAQ technologies were included in this report to be used as a potential future resource.

Acknowledgements

We cannot express enough thanks to Business Environment Council Limited for sponsoring this project and providing their continuous support. Specifically, we would like to thank Dr. Veronica Chan for being the liaison between Business Environment Council Limited and us. She was always willing to take time out of her busy schedule to provide her guidance and assistance to us. Her guidance, feedback, and understanding were greatly appreciated. The completion of this project could not have been accomplished without the help, support, and encouragement of our advisors, Professors Clark and Hou, as well as Professor Zeugner for helping us in our proposal.

Furthermore, we would like to thank Professor Peet, the IGSD office, and WPI for planning and providing this learning opportunity. Without them, this project center would not exist and we are thankful to them for creating this project opportunity for us with the Business Environment Council Limited.

Lastly, we want to offer Mall 3 our most sincere gratitude for permitting us to survey inside their shopping mall. The data from Mall 3 are a valuable part of this project and we were pleased to collaborate with Mall 3 to help improve the indoor air quality.

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Executive Summary

Indoor air quality (IAQ) is the comfortable range of parameters that influence the quality of the air such as the temperature, relative humidity, and concentration of gases. Buildings designed to keep outdoor air out of the buildings for energy efficiency coupled with inadequate ventilation can lead to the accumulation of indoor air pollutants. In Hong Kong, air ventilation is often controlled by mechanical ventilating air conditioning systems, or MVAC systems, MVAC systems can have poor ventilation contributing to poor IAQ. Poor IAQ can lead to two major health threats, Sick Building Syndrome (SBS) and Building Related Illnesses (BRIs). Around the year 2000, the government of Hong Kong conducted studies that showed that Hong Kong's IAQ was very poor. A major contributor to Hong Kong's poor IAQ is the ease with which fungi and bacteria can grow in Hong Kong due to its high humidity, temperatures, and crowded spaces.

The Hong Kong Environmental Protection Department (EPD) established the IAQ Management Group to confront the IAQ issue in Hong Kong. The IAQ Management Group initiated four main tasks of the IAQ Management Programme in 2003 to define satisfactory IAQ levels and raise the awareness of IAQ. Of the four main tasks of the IAQ Management Programme, two were focused on in this project, the *IAQ Certification Scheme for Offices and Public Places* and the IAQ Objectives that provided guideline values for a number of air pollutants. The latest study done on people's views and experiences with IAQ in Hong Kong released in March 2010, revealed that the majority of people were dissatisfied with the IAQ and were suffering from illnesses linked to indoor air pollution (Ipsos, 2010). In 2011, the tasks of the IAQ Management Programme were reviewed by the Hong Kong government's Department of Audit Commission, which gave recommendations for the improvement of initiatives carrying out the tasks (Audit Commission, 2011).

This project was another study on people's experiences with IAQ. The effectiveness of the Certification Scheme in improving the IAQ of Hong Kong shopping malls and the public's awareness of the Scheme was evaluated based on people's questionnaire responses. The questionnaires were printed in English and in Chinese. The IAQ Objectives were compared to the World Health Organization's (WHO) and various countries' recommended IAQ guidelines. In addition, the project involved researching newly released or developing products and technologies created to improve IAQ. Through the research, a few technologies were identified as potentially beneficial to Hong Kong buildings.

Questionnaires were conducted for a five-week period and data were analyzed. Comparisons of certification classes and certification statuses of shopping malls were conducted through Pearson's chi-square test, Mann-Whitney U test, Kruskal-Wallis test, and pairwise comparisons. Analyses of questionnaires can be found in the Results section and a copy of the questionnaire has been included in Appendix B.

In order to compare Hong Kong's IAQ Objectives to those of other countries and WHO (World Health Organization), research was conducted online and the standards for different airborne contaminants were put into tables where they could be easily compared. Conclusions were then drawn after evaluating the tables and recommendations were made to update Hong Kong's IAQ Objectives.

Research was also conducted in order to choose recent IAQ products and technologies that might benefit Hong Kong buildings. After research was completed, products were compared according to the needs of Hong Kong buildings so that the most relevant technologies could be recommended for the Hong Kong building owners to further review.

The results of this study showed that data collected of people's opinions of the IAQ of uncertified and certified shopping malls were not statistically different and therefore people perceived the IAQ of uncertified and certified malls to be of the same quality. Within the certification classes of 'Excellent,' "Good,' and uncertified, the results showed that people reported the IAQ of 'Excellent' class shopping malls to be worse than that of 'Good' and uncertified shopping malls. From these results, it was concluded that certified Hong Kong shopping malls might be letting their IAQ worsen between certification inspections. The recommendation followed that the physical measurements of the twelve IAQ parameters be taken in certified shopping malls to validate this conclusion. If the measurements support the conclusion, then it is recommended that the IAQ Certification Scheme request more frequent inspections of malls that are certified. From people's opinions of IAQ in uncertified malls, it was also concluded that uncertified malls may meet the requirements to become certified, and it was therefore recommended that uncertified malls that have not yet gone through the certification process do so.

Researching the IAQ Objectives resulted in observations that Hong Kong's IAQ Objectives are on par with those of other countries and WHO for the most part. Nevertheless, it was still recommended that the EPD update Hong Kong's IAQ Objectives due to three parameters that were significantly higher than those of other countries or WHO's. The three parameters were RSP (respirable suspended particulates), TVOC (total volatile organic compounds), and airborne fungi.

Lastly, researching the latest IAQ technology resulted in a synopsis of Enhanced Media Filtration (EMF) technology, Photocatalytic Oxidation, and the Honeywell IAQPoint2. Hong Kong shopping mall owners were advised to look out for updates and more research done on

EMF technology and Photocatalytic Oxidation. The mall owners should also determine if investing in the Honeywell IAQPoint2, or similar technologies, would be an asset for them after completing a cost-benefit analysis.

This project, consisting of three objectives, evaluated aspects of the IAQ Management Programme through analysis of questionnaire data, research on the IAQ Objectives, and research on technology that would help Hong Kong shopping malls better adhere to the IAQ Objectives.

1. Introduction

It is not uncommon to spend most of the day inside a building between school, work, and family time. Recently, an investigation of time budgets found that United States residents spend an average of 88% of their day inside buildings and 7% of their day inside vehicles. This meant that only 5% of the residents' time was spent outdoors (Robinson and Nelson, 1995). In 2010, the World Health Organization (WHO) estimated that four million people die every year from causes relating to indoor air pollution which is more than the death toll of acquired immunodeficiency syndrome (AIDS) and malaria combined (Bruce, Perez-Dapilla, Albalak, 2010).

Indoor air quality (IAQ) is defined as the comfortable range of "the temperature, humidity, ventilation and chemical or biological contaminants of the air inside a building" (NDSU, n.d.). IAQ is a measure of air cleanliness within a building and is important because people spend most of their time indoors. When IAQ is unsatisfactory, a condition known as Sick Building Syndrome (SBS) can occur in building occupants along with Building Related Illnesses (BRIs). SBS has been reported in many countries, including the United Kingdom, United States, China, Sweden, Denmark, Australia and the Netherlands. Symptoms of SBS consist of headaches, eye, nose, and throat irritation, coughing, nausea, dizziness, and difficulty in concentration (EPA, 2013; Godish 1995). Building occupants experience these symptoms within buildings but the symptoms disappear or improve significantly after the occupant leaves the building. Because the symptoms of SBS disappear or improve significantly after the building occupant leaves, SBS is hard to diagnose and treat. It is difficult to determine if SBS is caused by "insufficient ventilation or thermal control, inadequate maintenance of building systems," lighting, noise, or another factor but it can be determined that SBS is linked to specific buildings

(Godish, 1995). Though the exact cause of SBS cannot be determined, one major cause of the symptoms has been determined to be poor IAQ. Often times, building occupants don't have control over the indoor environment around them, which leads to recurring health problems among building occupants. In addition to health problems stemming from SBS, building occupants affected by BRI experience worsened SBS symptoms. BRIs are diagnosable illnesses whose sources can be traced back to specific air pollutants. Examples of BRIs include allergic reactions, hypersensitivity pneumonitis, humidifier fever, asthma, fiberglass dermatitis, and Legionnaires' Disease. Unlike SBS, BRI symptoms are non-specific and cannot be traced back to specific buildings (Godish, 1995).

The effects of SBS not only cause symptoms but can have additional consequences as well. The Cooperative Research Centres in Australia estimated that because of the lack of concentration and absence from work due to SBS, the Australian economy suffers a loss of $12 billion a year (CRC Association, 2012). In addition, the United States Environmental Protection Agency (EPA) found that, within its company, the EPA was losing up to $2 million per year due to SBS among its employees. It is estimated that if office workers in the United States lost "an average of 6 minutes productive concentration per day, the national impact on productivity would be projected to be on the order of $10 billion a year" (Godish, 1995). A national impact on the order of $10 billion per year means that each year the United States loses $10 billion assuming that each day every office worker is unproductive for six minutes due to SBS. This estimation only includes United States office workers and does not take into account other professions and their loss of productivity from SBS. Concerns for IAQ span worldwide as people's health is affected by the unsatisfactory air in buildings. In 2000, indoor air pollution accounted for approximately 41,000 deaths due to respiratory diseases in Africa. Also, in the year 2000, indoor smoke caused 118,000 deaths in the East-Mediterranean region: 22,000 from respiratory diseases and 95,000 from respiratory infections. In the East-Mediterranean, much of the indoor air pollution can be attributed to indoor smoke from cooking. Similarly, in the same year, 26,000 Americans died from respiratory diseases and infections attributed to indoor smoke (WHO, n.d.). In China particularly where it is known to have bad outdoor air pollution, the improvement of IAQ is essential.

In China, outdoor air pollution is a problematic issue. Smog generated from factories, vehicles, and coal-burning enshrouds many cities. Pedestrians wear dust masks to help shield themselves from harmful air particles. Without much success, Beijing has made many actions to curb the smog problem, such as shutting down polluting factories, limiting the number of vehicles on the road, and banning outdoor barbecues (Li, 2013).

Even still, days when cities are blanketed in smog are not uncommon. On October 21, 2013, the city of Harbin was shut down by severe smog. The airport, elementary and middle schools, and some public bus routes were forced to close as visibility was reduced to ten meters. An index that measures particulate matter ($PM_{2.5}$), which consists of small airborne particles posing the greatest health risk, reached a level 3.3 times greater than the hazardous level. The smog was blamed on the first day of heating being started for winter (Rose, 2013). On November 7, 2013, Shanghai's air quality reached "severe pollution" levels as smog covered the city, forcing many to stay indoors. Shanghai's education authorities warned students to avoid outdoor activities and to stay indoors hoping to protect them from exposure to harmful outdoor air pollutants (Li, 2013).

With more people staying indoors to protect themselves from the outdoor pollution, the demand for cleaner indoor air has significantly increased. Many businesses, such as Central

China Television and China Telecom, and Beijing's local government have sought to install equipment for air pollution control in their offices to lower the concentration of $PM_{2.5}$. The Chinese market for air purifiers is expected to grow 34% per year over the next five years, as of 2013 (Shao, 2013).

With a greater demand for cleaner IAQ, the Hong Kong government recognized the problems of IAQ after office building breakouts of illnesses were reported by employees. After some investigation, the cause of these office illness breakouts was traced back to IAQ issues. The Total Exposure Assessment Methodology (TEAM) study conducted by the United States EPA determined that concentrations of air pollutants were significantly higher in indoor air than outdoor air (Wallace, 1987). The fact that in Hong Kong, approximately 40% of citizens are students while another 30% are office workers who spend most of their time indoors, made the results of the TEAM study a major concern (Chan, Guo, Lee, Li, 2002). In 1986, the Hong Kong Environmental Protection Department (EPD) was created "to co-ordinate and carry out pollution prevention and control activities." The EPD's vision is to create a Hong Kong

> which enjoys an environment that is both healthy and pleasant; in which the community places a premium on sustaining such an environment for both themselves and future generations, and pursues sustainable development; and in which the community enjoys a reliable and safe energy supply at reasonable prices, while improving energy efficiency, promoting energy conservation and minimizing the environmental impacts from the production and use of energy (HKEPD, 2005).

The Hong Kong EPD set in motion investigations to evaluate IAQ within its region and the results confirmed unsatisfactory IAQ including unhealthy levels of airborne bacteria in many of its buildings.

The Hong Kong government has taken some major steps to address the issues of IAQ in Hong Kong. Under the management of the EPD, the government established the IAQ

Management Group comprised of three government bureaus and ten departments in 1998 (Burnett, 2005; The Government of the HKSAR IAQ Management Group, 2003b). This management group produced guidelines for IAQ in various enclosed places, including commercial buildings. Under the EPD, the IAQ Objectives was initiated in 2003 to define acceptable levels of twelve parameters that affect IAQ and to improve IAQ by creating the *IAQ Certification Scheme for Offices and Public Places*. The Certification Scheme is a voluntary program for buildings to obtain a certificate that can be displayed to show that they have acceptable IAQ should the buildings fulfill the IAQ Objectives. As of February 2014, the scheme had 420 buildings participating, 57 of which were shopping malls (Indoor Air Quality Information Centre, 2014).

The IAQ in Hong Kong shopping malls is very important. Many people spend much time working or shopping in malls, and malls play a large role in Hong Kong's tourism and economy. Forty-eight million visitors entered Hong Kong in 2012 and accounted for 33% of retail sales. There were approximately sixty-four thousand establishments in the retail industry in 2012 (Hong Kong Economy, 2013). Retail industry establishments include supermarkets, electrical goods, medicine, furniture, optical, stationary and gift shops, jewelry, clothing, and shoe stores, all of which can be found within Hong Kong malls (Cheung, 2011). Through the style and structure of Hong Kong malls, visitors are capable of buying a wide variety of goods and products in a centralized location. The convenience of the shopping malls makes them popular among tourists as well as Hong Kong locals. Retail trade accounts for nearly nine percent of Hong Kong's total employment, which is around 320,000 people, and about four percent of Hong Kong's gross domestic product (Hong Kong Economy, 2013). Since malls are an important aspect in Hong Kong's economy and shopping is not only a tourist attraction but also part of the local culture, good IAQ needs to be maintained in shopping malls to protect the health and comfort of mall occupants.

One cause of poor IAQ in Hong Kong buildings, including shopping malls, is inadequate ventilation rates of mechanical ventilating air-conditioning (MVAC) systems. MVAC systems are widely used in Hong Kong and can trap bacteria in their air ducts, allowing for the proliferation of colonies of airborne bacteria and fungi if not properly maintained or cleaned (Atencio, 1999; EPA, 2012, 2013). The MVAC systems' contributions to poor IAQ as well as the previously mentioned irritants, such as smoke and outdoor air pollution, are important issues that should be addressed through emerging updated or new technology.

Technology is ever changing and being updated and it is important for Hong Kong to know of the latest technology in IAQ improvement. Being well informed in the latest IAQ technology will allow building owners to make a well-informed decision when an upgrade or new part is needed. New technology may be more energy efficient, saving money and better serving the needs of building occupants. The EPD in 2003 recommended MVAC systems as the most effective way to achieve good IAQ. Since 2003, more advanced technologies relating to IAQ have been developed with some technologies capable of being incorporated into MVAC systems. Advanced air conditioners and upgrades will make for even better IAQ in Hong Kong buildings. Certain shopping malls in Hong Kong have started using new technology to create environments with good IAQ for their patrons. An example of up-to-date technology used in a Hong Kong shopping mall is a carbon dioxide (CO_2) detector that adjusts the level of CO_2 in the air to a healthy level if it detects a CO_2 concentration that is too high. It is important to investigate the technology Hong Kong shopping malls are currently using and to research the latest IAQ technology to investigate if there is new technology Hong Kong mall managements might be interested to learn more about.

This project, sponsored by Business Environment Council Limited sought, through surveying, to evaluate public awareness of the IAQ Certification Scheme in Hong Kong and to investigate whether there is a difference in people's perceptions of IAQ in shopping malls that are certified and those that are not. The purpose of this project included researching and comparing Hong Kong's IAQ Objectives to international IAQ guidelines to determine if Hong Kong's IAQ Objectives are out of date. This project also included examining the most recent IAQ technology and providing summaries of the technology to be used as a future resource. Summaries of the IAQ technologies are not intended to be recommendations to shopping malls but to serve as a brief description for shopping malls to determine whether they want to conduct further research on the technology.

2. Background

2.1. Indoor Air Quality (IAQ) & its Significance

As people are dependent upon the oxygen in the air to live, the air quality directly impacts a person's health and comfort. On average, an adult breathes 12 – 16 breaths per minute totaling up to 17, 289 – 23, 040 breaths per day (John Hopkins Medicine, n.d.). Most of these breaths are taken in an indoor environment as most people tend to spend the majority of their time indoors between school, work, and their homes. Satisfactory indoor air quality (IAQ) contributes to a person's comfort because it reduces the risk of a person becoming sick from indoor air pollutants. Achieving satisfactory IAQ enhances the health of building occupants by lowering the amount of or removing harmful air pollutants in the air that would otherwise be inhaled.

Unsatisfactory IAQ can arise from pollutants and/or inadequate ventilation. The types of pollutants vary from building to building but include combustion gases from cooking techniques, emissions from paint, cleaning or maintenance supplies, building material odors, and interior decorations (BEAM Society Limited, 2012). Inadequate ventilation further enhances the problems caused by pollutants as they are not effectively circulated out of the building or diluted by fresh outdoor air coming in. In certain cases, the outdoor air may be polluted and can worsen the indoor air as it is circulated inside buildings. Air ventilation within commercial buildings is typically controlled by MVAC systems in Hong Kong. MVAC systems control the IAQ through a series of heating, cooling, humidification, de-humidification, filtration, and air flow (Atencio, 1999). After the oil crisis in the late 1970's, energy conservation building techniques were adopted. These techniques further inhibited ventilation throughout buildings. Energy conservation techniques affected "the design, construction, and management of buildings" and thus, the buildings were dubbed with the term 'tight building syndrome.' Tight building syndrome refers to buildings "that ha[ve] been designed and constructed to attain and maintain low air infiltration conditions regardless of the percentage of outside air used for ventilation" (Godish, 1995). Buildings with tight building syndrome are energy efficient in that unwanted outside air cannot penetrate through. Buildings with tight building syndrome are common nowadays as the world faces an imminent energy crisis. Building designs contribute to energy savings because if the frigid, winter air cannot leak through windows and gaps in the walls then less energy will have to be spent on heating the building. Despite the savings, these building designs along with inadequate ventilation can result in the accumulation of indoor air pollutants.

The accumulation of indoor air pollutants poses health threats and causes discomforts such as SBS and BRIs. Health problems can range from minor to major depending on the person and amount of exposure. SBS can be categorized under minor health problems which include irritation of eyes and nose, dizziness, headaches, or asthma attacks. BRIs can be categorized under major health problems which include respiratory diseases, heart conditions, and potentially cancer depending on the pollutants present in the air as well as the person and amount of exposure (US EPA, 2013). Table 2.1 below lists some common indoor air pollutants, their sources, and their contributing health impacts.

Table 2.1: Examples of Pollutants, Sources and Health Impacts (POST, 2010; The Audit Commission, 2011)

Pollutant	Sources	Health Impacts
Nitrogen dioxide (NO_2)	Heating and cooking appliances, smoking	Respiratory symptoms & eye irritation
Carbon monoxide (CO)	Heating and cooking appliances, smoking, vehicle emissions	Headaches, chest pain, confusion, rapid breathing, lethal at high levels
Particulate matter (PM)	Cooking and aerosols	Reduced lung function and increased risk of heart and respiratory disease
Radon (Rn)	Ground gases, granite building materials	Lung cancer
Volatile organic compounds (VOCs)	Cleaning products, paints, printers, furniture, smoking	Respiratory tract irritation, possible chances of cancer
Ozone (O_3)	Cleaning products, paints, photocopiers, and printers	Respiratory tract irritation, sore throat, tearing, burning, and pain in the eyes
Carbon Dioxide (CO_2)	Smoking and cooking appliances	Headaches, dizziness, and nausea
Formaldehyde (HCHO)	Smoking, paints, furniture, certain wood products, adhesives	Eye and respiratory irritation, lung tissue damage if high concentrations

Outbreaks of SBS and BRIs around the world in the late 1900s led to the development of investigative protocols in many countries such as the United States and Canada. Investigative protocols in the United States include the National Institute of Occupational Safety and Health

(NIOSH) Protocol, USEPA/NIOSH Protocol for In-House Protocol, California Protocol, and American Industrial Hygiene Association (AIHA) Protocol. In Canada, the Public Works Canada (PWC) Protocol and Ontario Interministerial Committee (OIC) Protocol were developed as standardized procedures for federal government officials to investigate the IAQ of buildings. Similarly, in Europe IAQ investigations are conducted through public services such as the Danish Building Research Institute (DBRI) Protocol and the N\ordic Ventilation Group (Nordtest Protocol). IAQ can be assessed in terms of many parameters such as temperature (T), relative humidity (RH), airborne bacteria counts (ABC), carbon dioxide (CO_2), carbon monoxide (CO), and respirable suspended particles (RSP). All of the mentioned protocols consist of an initial background assessment followed by an on-site investigation and in cases where the problem is particularly hard to pinpoint or resolve, a second more thorough on-site investigation is performed. The protocols are typically carried out by a team of industrial hygienists, epidemiologists, and professionals with extensive knowledge on heating and ventilating air-conditioning (HVAC) systems. In addition to government efforts to evaluate IAQ, private companies such as the Honeywell Indoor Air Quality Diagnostics and Clayton Environmental Consultant were founded and are capable of providing their services nationally within the United States and internationally (Godish, 1995).

In addition to the development of investigative protocols, as more outbreaks and cases of SBS and BRIs occurred, studies on the effects and the causes of the symptoms followed. In the 1980s and 1990s, many studies on SBS and BRIs were published with their results. The studies could not pinpoint a single perpetrator for SBS. However, studies on the exposure of humans to VOCs published by Taylor and Francis Ltd. have related air pollutants contributing to poor IAQ to illnesses or signs of SBS, i.e. low productivity (Koren, Graham, & Devlin, 1992; Otto, Hudnell, House, Mølhave & Counts, 1992). As for BRIs, in 1991 the United States EPA reported that BRIs could be traced back to airborne building contaminants (EPA, 1991). In 1978, WHO held the first International Symposium on Indoor Climate where it recognized the importance of indoor air pollution and the likelihood of it being a major cause of the adverse health effects that broke out in the 1970s. Another symposium on IAQ followed in 1981, taking place in Amherst, Massachusetts, as well as a third in Stockholm, Sweden in 1984. Following each symposium, a Working Group addressing the IAQ problem was formed. The third Working Group met from the 27th to the 31st of August in 1984 and in the report on their meeting, they related excessive complaints from people who spent prolonged time in buildings to IAQ issues. The third Working Group also proposed solutions to the problems found from the people's complaints (WHO, 1986). As the world was discovering the causes of SBS and BRIs, so was Hong Kong, and its Environmental Protection Department (EPD) was prepared to take action to evaluate its individual IAQ situation.

2.2. IAQ of Hong Kong

Within Hong Kong buildings, MVAC systems are common due to Hong Kong's hot and humid climate. The humid, tropical climate eliminates the need for Hong Kong buildings to heat the air, resulting in the use of MVAC systems instead HVAC systems. In addition to causing increased air-conditioning use, Hong Kong's hot and humid climate amplifies the growth of mildew and other fungi inside buildings as their optimal growth environment is warm and moist. The rate of proliferation of airborne bacteria is increased with an increase in temperature and relative humidity. The hot, humid and tropical climate of Hong Kong becomes the perfect environment for airborne bacteria to build up in the air and further deteriorate IAQ. Airborne bacterial and fungal counts are also increased in crowded places, which are extremely common in Hong Kong. Hong Kong's dense population of approximately 7.15 million, as well as its booming economy and employment density, makes it a very crowded place (Yee, 2011; Hong Kong Information Services Department, 2013). Whether on the city street, going shopping in a mall, or on the job, there is bound to be a mass of people around you doing the same. Over the years, more sources of indoor air pollutants have been introduced in workplaces and in public spaces. These sources include modern office equipment such as laser printers, synthetic building materials, glues containing organic solvents, and chemical-based cleaning agents. For schools with limited budgets, air conditioning systems are installed in windows limiting the supply of fresh air into classrooms (Chan, Guo, Lee, & Li, 2002). With decreased airflow from the outside, air pollutants are capable of accumulating in classrooms without any means of dilution, thus exposing children to high levels of bacteria. Hong Kong schools are examples of a building type that can be affected by poor ventilation and high levels of indoor air pollution.

Another type of Hong Kong building that can be affected by poor ventilation and high levels of indoor air pollution are shopping malls. Based on its history, Hong Kong has long been seen as a trading port for goods from all over the world (Carroll, 2007). Even today, Hong Kong is known for its endless opportunities for shopping and numerous shopping malls. It is not uncommon for shopping malls to be connected to Mass Transit Railway (MTR) stations, offices, or residential buildings (MTR, 2011). The ease and convenience of shopping mall locations encourage shopping and tie residential and commercial areas together. Shopping is not only a key to Hong Kong's tourism and economy but also a part of the Hong Kong culture. Due to the popularity of Hong Kong shopping malls, they can easily become overcrowded resulting in the question of whether the shopping malls' MVAC systems are providing enough ventilation. If the MVAC system is not providing enough ventilation, concentrations of indoor air pollutants will increase, especially carbon dioxide levels from the exhalation of mall patrons (Li, Lee, & Chan, 2001). Therefore, it is important for mall managements to ensure that MVAC systems and other technologies used are capable of providing satisfactory IAQ.

In November 1993, the Hong Kong Environmental Bureau recognized the importance of IAQ and its resulting consequences on public health after reviewing the *Second Review of the 1989 White Paper on Pollution in Hong Kong* (Planning, Environment and Lands Branch, 1993). The *1989 White Paper on Pollution in Hong Kong* was a government publication recognizing Hong Kong's serious pollution problem as the government estimated that 5, 000 tons of trash was produced per day in 1989. The *1989 White Paper on Pollution in Hong Kong* outlined Hong Kong's ten year plan to combat pollution through legislation and for the first time ever, planning with respect to the environment (EPD, 1989; 2005). To combat the issue of IAQ within Hong Kong, the 1995 Consultancy Study completed in 1997 by the Environment Bureau provided a list of recommendations to improve the IAQ and stressed the need to educate the public on the importance of IAQ. The responsibility of carrying out the 1995 Consultancy Study recommendations fell upon the inter-departmental IAQ Management Group created in September 1998. The IAQ Management Group was comprised of three government bureaus and ten government departments headed by the Deputy Secretary of the Planning, Environment and Lands Bureau (Burnett, 2005; The Government of the HKSAR IAQ Management Group, 2003b). The IAQ Management Group proposed the IAQ Management Programme in November 1999 to fulfill the 1995 Consultancy Study recommendations. The overall goal of the Programme was "to improve IAQ in buildings and public places, protect public health in indoor environment and promote public awareness of the importance of IAQ" (The Audit Commission, 2011). Program tasks were assigned to government departments ENB, EPD, Electrical and

Mechanical Services Department, and Architectural Services Department (The Audit Commission, 2011). Program tasks included:

a. Educating the public to increase IAQ awareness and distributing IAQ information at an IAQ information center
b. Publishing guidance notes for the management of IAQ within offices and public places
c. Determining IAQ objectives to be used as assessment benchmarks
d. Creating an IAQ certification scheme

This project focused primarily on two tasks: IAQ Certification Scheme and IAQ Objectives. A diagram of the tasks under the IAQ Management Programme is provided in Figure 2.1, followed by descriptions of each program task.

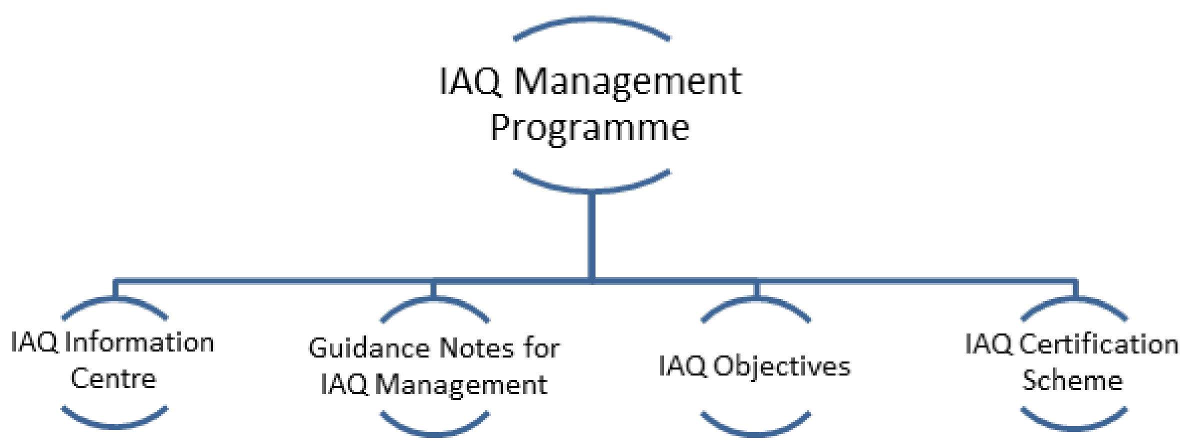


Figure 2.1: IAQ Management Programme and its Tasks (The Audit Commission, 2011)

2.2.1. IAQ Information Centre

Under the EPD, educational and informative materials were created to inform the public about IAQ and its importance. EPD efforts included advertisements, mass media promotions, seminars, and school visits among others. In total, the EPD has published two booklets, twelve information leaflets, and twenty posters on IAQ. Furthermore, in 2001 the EPD created an IAQ Information Centre in Kowloon Tong and online (http://www.iap.gov.hk). The published booklets, leaflets, and posters can all be viewed online at the IAQ Information Centre. The IAQ Information Centre serves to promote good IAQ among the public and school children through distribution of informational materials and school visits. The IAQ Information Centre is also responsible for processing and maintaining IAQ Certification Scheme records.

2.2.2. *Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places (GN)*

The publication *Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places* (GN) developed and endorsed by the IAQ Management Group, gave voluntary guidelines for the management of IAQ and provided information for the public to understand IAQ. The GN was derived from international standards, such as WHO and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). The GN addressed IAQ topics including the factors affecting IAQ, IAQ Objectives, IAQ Certification Scheme, strategies to achieve the IAQ Objectives, IAQ management and investigation strategies, mitigation strategies and professional assistance. The GN is not legally binding and is voluntary (The Government of the HKSAR IAQ Management Group, 2003b).

2.2.3. Hong Kong IAQ Objectives

To accomplish the assessment benchmarks, the Hong Kong IAQ Objectives was initiated in 2003 to quantify acceptable IAQ parameters and promote IAQ awareness (Burnett, 2005). The IAQ Objectives were published and explained in the GN (The Government of the HKSAR IAQ Management Group, 2003b). Derived from health-based air quality standards such as WHO, United States EPA and various countries' IAQ guidelines, the IAQ Objectives were intended to lower the chances of inducing Sick Building Syndrome and improve the comfort and well-being of all building occupants. The IAQ Objectives established benchmarks to define satisfactory levels when measuring IAQ parameters and created guidelines for measuring and assessing IAQ. The IAQ Objectives assigned specific guideline values to twelve parameters that affect IAQ; three physical (temperature, relative humidity, air movement), eight chemical (CO_2, carbon dioxide, carbon monoxide, respirable suspended particulates, nitrogen dioxide, ozone, formaldehyde, total volatile organic compounds, radon) and one biological – airborne bacteria count (The Government of the HKSAR IAQ Management Group, 2003b). Values for each of the twelve parameters were created as benchmarks for 'Excellent' and 'Good' class (see Table 2.2 and 2.3). 'Good' class values are the maximum allowable values for each of the IAQ parameters. Values measured greater than 'Good' class values are considered unsatisfactory. The purpose of the IAQ Objectives was to establish the *IAQ Certification Scheme for Offices and Public Spaces*, a voluntary certification for buildings to show that they have satisfactory IAQ.

Table 2.2: Criteria for IAQ Certification Scheme (Burnett, 2005)

Parameter	Units	'Excellent'	'Good'
Temperature (T)	Celsius (ºC)	20 – 25.5	< 25.5
Relative Humidity (RH)	%	40 – 70	< 70
Air Movement	meters per second (m/s)	< 0.2	< 0.3
Carbon Dioxide (CO_2)	parts per million (ppm)	< 800	< 1000
Carbon Monoxide (CO)	ppm	< 1.7	< 8.7
	$\mu g/m^3$	< 2,000	< 10,000
Respirable Suspended Particulates (RSP) (PM_{10})	microgram per cubic meter ($\mu g/m^3$)	< 20	< 180
Nitrogen Dioxide (NO_2)	$\mu g/m^3$	< 40	< 150
	parts per billion (ppb)	< 21	< 80
Ozone (O_3)	$\mu g/m^3$	< 50	< 120
	ppb	< 25	< 61
Formaldehyde (HCHO)	$\mu g/m^3$	< 30	< 100
	ppb	< 24	< 81
Total Volatile Organic Compounds (TVOC)	$\mu g/m^3$	< 200	< 600
	ppb	< 87	< 261
Radon (Rn)	becquerel per cubic meter (Bq/m^3)	< 150	< 200
Airborne Bacteria Count (ABC)	colony forming units per cubic meter (CFU/m^3)	< 500	< 1,000

Table 2.3: Measurement Devices for IAQ Parameters (Burnett, 2005)

Parameter	Measurement Device
T	Electronic thermometer
RH	Electronic psychrometer
Air Movement	Electronic anemometer
CO_2	A real-time monitor, such as a non-dispersive infrared (NDIR) analyzer or electrochemical oxidation device
CO	
RSP	Optical scattering or piezoelectric real-time monitor
NO_2	Tedlar bag with analysis by chemiluminescence based NO_2 analyzer; absorbent filter containing triethanolamine and analysis by spectrophotometry at wavelength of 545 nanometers (nm); or real-time portable analyzer
O_3	Real-time instruments, such as heated metal oxide semiconductors, electrochemical, ultraviolet (UV) photometric or chemiluminescence detector
HCHO	High performance liquid chromatography (HPLC) for active or passive sampling and analysis; colormetry for passive sampling and analysis
TVOC	Passivated canisters or solid sorbents followed by direct flame ionization detection
Rn	Electronic monitor that complies with the device performance test specified by the EPA National Radon Proficiency Program Handbook
ABC	Samplers such as Andersen multi-hole impactor, Reuter Centrifugal Sampler (RCS) Surface Air System (SAS) bioaerosol or cyclone scribbler. Soy agar plates for culture and analysis of airborne bacteria

2.2.4. IAQ Certification Scheme

A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places, a government publication, explained the IAQ Certification Scheme including the steps on obtaining and maintaining the certification and the evaluation process (The Government of the HKSAR IAQ Management Group, 2003a). The Certification Scheme has two classes of acceptance, ‘Excellent’ and ‘Good’, and it pertains to “buildings or totally enclosed areas for the use as offices or public places" that have MVAC systems such as "office buildings, shopping malls, hotels, restaurants, theatres cinemas and funeral parlours" (The Government of the HKAR IAQ Management Group, 2003a). Participation in the scheme is free and voluntary, but the building owner is responsible for the costs associated with the evaluation and maintenance process, such as hiring IAQ Certification Issuing Bodies (CIBs) to assess the IAQ of the building. To obtain the certificate, the average of each of the twelve IAQ parameters must not exceed the guideline value for satisfactory levels during evaluation. For the evaluation, the parameters are measured on an eight-hour basis. If it is not feasible to take an eight-hour continuous measurement, another measuring strategy is used. In the alternate strategy, the measurements are taken in four 30-minute time-slots. The certificate lasts for twelve months; to renew it, all of the parameters must be evaluated once every five years, and for the four years in between, only carbon dioxide and respirable suspended particulates (RSP) must be evaluated every year if there are no alternations to the use of the building that may negatively impact the IAQ and if there is no major change to the maintenance of the MVAC system. The certification generally certifies the building as a whole, but building owners can certify specific parts of the building (The Government of the HKSAR IAQ Management Group, 2003a).

Buildings are only certified if all the IAQ parameters fulfill the 'Good' class guideline values. The unsatisfactory values are values which are greater than the values listed for 'Good' class (Chan et al., 2010). There is an alternative measurement of TVOC for the 'Good' class; the TVOC criterion 'Good' value can be substituted with values of ten commonly found individual volatile organic compounds (VOCs). If the level of TVOC in a building exceeds the guideline value specified in Table 2.2 then the individual VOC causing the parameter to be over the 'Good' class value may be measured. If the amount of each of the VOCs in the building is less than the guideline values given in Table 2.4, then the TVOC objective for 'Good' class can still be considered met. The values and names of the ten VOCs are located in Table 2.4 (The Government of the HKSAR IAQ Management Group, 2003a). Another parameter, airborne fungi, will be included in the next review of the Certification Scheme. Research studies have shown that airborne fungi are capable of producing metabolites that are toxic to human cells. These toxins can cause various effects in human bodies such as suppressing the immune system and causing cancer (Rao, Burge, & Chang, 1996).

Table 2.4: Criteria for individual VOCs for 'Good' class for TVOC objective of IAQ Certification Scheme (The Government of the HKSAR IAQ Management Group, 2003a)

Compound	Good Class
Benzene	16.1 $\mu g/m^3$
Carbon tetrachloride	103 $\mu g/m^3$
Chloroform	163 $\mu g/m^3$
1,2-Dichlorobenzene	500 $\mu g/m^3$
1,3-Dichlorobenzene	200 $\mu g/m^3$
Ethylbenzene	1447 $\mu g/m^3$
Tetrachloroethylene	250 $\mu g/m^3$
Toluene	1092 $\mu g/m^3$
Trichloroethylene	770 $\mu g/m^3$
Xylene (o-, m-, p-isomers)	1447 $\mu g/m^3$

In addition to obtaining a certificate that can be displayed on the doors or windows of the building, fulfilling the certification parameter requirements will award the building with five Building Environmental Assessment Method (BEAM) credits. The BEAM scheme, established in 1996, is a voluntary assessment for residential, commercial, institutional, and industrial buildings. The purpose of BEAM is to "enhance the quality of buildings in Hong Kong" and to make buildings more sustainable and environmentally friendly. BEAM awards a label that represents a building's quality level with regards to safety, health, and comfort as well as the building's performance level with regards to environmental and social aspects. According to BEAM, "a certified BEAM building is safer, healthier, more comfortable, more functional, and more efficient than a similar building that does not achieve the level of performance prescribed in BEAM" (BEAM Society Limited, 2012). BEAM credits are awarded for complying with the guideline values of different IAQ parameters in the IAQ Objectives: one credit for complying with the CO, NO_2, and O_3 guideline, one credit for complying with the RSP guideline, one credit for complying with the VOC guideline, one credit for complying with the formaldehyde guideline, and one credit for complying with the radon guideline. The areas subjected to BEAM examination are site aspects, material aspects, energy use, indoor environment quality, and water use. Each area contributes differently to the overall building performance and so BEAM has accordingly taken into account the impact and significance of each area by assigning credit weights. The credit weights of site aspects, material aspects, energy use, indoor environment quality, and water use are 25%, 8%, 35%, 20% and 12% respectively. Each credit awarded for complying the IAQ Certification Scheme will fall under the BEAM category of indoor environment quality and be weighted at 20%. Among all the areas looked at by BEAM, indoor environment quality falls in the middle in terms of importance after energy use and site aspects. BEAM credits are valuable to shopping malls because becoming BEAM certified grants shopping malls more saleable area. BEAM certified shopping malls can advertise more square footage and gain more profit per square foot. Complying with the IAQ Certification Scheme will not only guarantee better IAQ but will also help to turn a profit after becoming BEAM certified (BEAM Society Limited, 2012).

2.3. International IAQ Programs

There are various IAQ programs comparable to Hong Kong's IAQ Certification Scheme in that they encourage the assessment, monitoring, and/or promotion of IAQ. Some programs also have set up IAQ guidelines similar to Hong Kong's IAQ Objectives.

2.3.1. European Commission

For example, the European Commission launched the "Lowest concentration of interest" approach in 2010. Through this, professionals have considered the lowest concentration above which a pollutant may affect people in the indoor environment. The initiative was coordinated by the Institute for Health and Consumer Protection, one of seven scientific institutes in the European Commission's Joint Research Center. The center provides scientific and technical support for European Union policies regarding food, consumer product chemicals, and the public health of European citizens. The center conducted research for the European Environment and Health Strategy, a government initiative started by the European Union in 2004 to understand the correlation between environmental factors and people's health. The center's research resulted in the "Lowest concentration of interest" policy which defined the maximum safety level for IAQ parameters (European Commission, 2013). The "Lowest concentration of interest" policy was geared towards children. The studies focused on correlating environmental factors to childhood respiratory diseases, asthma and allergies, neurodevelopmental disorders, childhood cancer, and disruption of the endocrine system. The European Environment and Health Strategy also aimed to set up a community information system where people could easily access information on the link between the environment and health, to launch projects to collect data and monitor select environmental pollutants and their effects, and to develop policies based on the conclusions drawn from the projects. The policies were meant to lower health risks for European habitants by monitoring environmental factors that correlate to poor health (Europa, 2005). The policy using the "Lowest concentration of interest" approach involved a list of more than 100 volatile organic compounds that were often detected in emission tests of building materials and indoor products. A group of toxicologists and experts in emission testing had the responsibility of establishing the lowest concentration of each of the volatile organic compounds, above which the indoor environment could be negatively affected (European Commission, 2013).

2.3.2. United States

Various states in the United States have created IAQ programs and guidelines that provide the public with educational services about IAQ and exposure limits for airborne contaminants. Certain states have funded air quality experts and different stakeholders to create the guidelines, such as Texas, while others have formed their guidelines as variations of the United States' federal guidelines under the Occupational Safety and Health Act.

2.3.2.1. State of Texas

The IAQ Program in Texas distributes information to the public about indoor air pollutants and methods to decrease the amount of contaminants in the air. It answers questions about health risks associated with certain indoor air contaminants, sources of the contaminants, and ways to improve IAQ and indoor ventilation. It also conducts IAQ seminars for the public and provides information on resources the public can use to get more information (Texas Department of State Health Services, 2012). Voluntary IAQ Guidelines for Texas Government Buildings became effective on December 22, 2002 for all government buildings, including public school buildings. The Texas Department of State Health Services monitored the creation of the guidelines. The department organized groups of volunteer stakeholders to help develop the guidelines. The guidelines, as well as the information and seminars provided through Texas'

IAQ Program, are voluntary. The guidelines, information, and seminars serve as resources that can be utilized by any government building or Texas resident that is interested in IAQ (Texas Department of State Health Services, 2010).

2.3.2.2. State of California

Under the California Department of Public Health, the IAQ Program was started in 1983 as the first state IAQ program in the United States. The purpose of California's program is to promote and coordinate the investigation of IAQ as it relates to causes, effects, and prevention of poor IAQ (CDPH, 2014; CDPH, n.d.). The state funds an interdisciplinary team that includes five fulltime research scientists and chemists as of 2014. The team uses the funding to conduct research studies aimed at discovering causes of and ways to control indoor air pollution in California. Through the program, a working group called the California Interagency Working Group on IAQ organizes activities on IAQ for key government agencies, academic institutions, and industry stakeholders (CDPH, 2014). The state of California has also developed an occupational safety and health program through an agreement with the United States Occupational Safety and Health Administration (OSHA, 2014a). The program set exposure limits for chemical airborne contaminants in workplaces in California and enforces these standards with an enforcement unit. The standards were based on recommendations from technical support and the exposure limits for airborne pollutants set by other states and countries; California air pollutant standards are updated as the state deems necessary (Occupational Health Branch, 2014; OSHA, 2014a). Airborne contaminants include carbon dioxide, carbon monoxide, and formaldehyde. The enforcement unit has legal jurisdiction over every workplace in California and conducts inspections if the unit receives a report or complaint about an occupational safety and health hazard. The unit also runs an inspection program that focuses on industries with the most occupational hazards. California's occupational safety and health program is based off of the United States Occupational Safety and Health Act enacted in 1970 (OSHA, 2014a).

2.3.2.3. United States Federal Government

The Occupational Safety and Health Act provides standards that employers in the United States must comply with to ensure safe and healthy workplaces for employees. These standards include exposure limits for airborne contaminants (OSHA, 2014c). Under the Act, the Secretary of Health and Human Services is tasked to establish and supervise education and training programs in which employees and employers learn how to recognize and prevent unhealthy working conditions. The Act also mandates that the Secretary consult with and provide advice for employers, employees, and organizations on how to prevent occupational illnesses and injuries (OSHA, 2004). In addition to the Secretary's training programs, the Occupational Safety and Health Administration provides educational materials and grants to help businesses and employers train their workers themselves. The Occupational Safety and Health Administration's website provides links to training courses and materials and to important information regarding the training programs (OSHA, 2014d).

The Occupational Safety and Health Administration enforces the standards of the Act by conducting inspections of workplaces without advance notice (OSHA, 2014b). However, a company or employer identified as implementing procedures to prevent occupational hazards and providing training for employees in strategies to achieve a safe working environment may be exempt from random inspections for up to one year after the company's last consultation (OSHA, 2004). The Administration also conducts inspections in response to worker complaints and referrals and targets industries with high employee injury or illness rates, such as chemical facilities. In this way, the Administration is similar to California's occupational safety and health program's enforcement unit (OSHA, 2014b).

2.3.3. United Kingdom (UK)

In Europe, IAQ UK is an independent organization that works for the promotion of good IAQ in people's homes and at their places of work. There are no standards or regulations on IAQ in the UK as of February 2014, so IAQ UK does not enforce IAQ standards. The organization rather focuses on education and providing information for anyone who wishes to learn more about IAQ. The organization hosts events in which employers can learn about the latest research in IAQ and ways to maintain healthy environments in their workplaces. Employers are also informed of resources that can provide them with more information about IAQ. The events, as well as the latest news regarding IAQ are posted on the IAQ UK website. The IAQ UK website also provides helpful resources such as a chart indicating which harmful chemicals can come from common products in people's households. In addition, the website provides detailed descriptions of every chemical contaminant mentioned in its resources and the history, production, chemical structure, and health effects of the contaminant (IAQUK, 2014).

IAQ UK uses its website and other tools to complete five major objectives. Objective 1 is to provide the public with a clear reference regarding IAQ. The IAQ UK website lists resources for learning more about IAQ and its effects on health, comfort, and productivity. All of the information and resources presented on the website are accessible to every person worldwide without any requirements such as membership or subscription. Objectives 2 and 3 are related. Objective 2 involves providing practitioners and students with training through a course in which they gain a deep understanding of IAQ. Objective 3 involves making sure IAQ practitioners are as knowledgeable as possible in IAQ before they influence IAQ through their jobs. Objective 3 can also be achieved through the course. Upon completing the course, the practitioners and students are awarded with “The Awareness,” a training certificate. The training certificate is a small token to represent the completion of the IAQ Awareness Course. However, the real reward of completing the course is the knowledge and skills gained that help the practitioners better do their jobs and students have more awareness of IAQ. The course teaches how to achieve satisfactory IAQ in the workplace, methods for identifying, evaluating, and monitoring ventilation systems, and outlines IAQ legislation. The fourth objective consists of staying in correspondence with the government and encouraging the government to initiate IAQ programs and practices for the betterment of IAQ. Finally, the fifth objective involves pooling the knowledge from practitioners and IAQ experts with different backgrounds to come up with the best ways to improve IAQ (IAQUK, 2014).

2.3.4. Comparisons of International IAQ Programs with Hong Kong’s IAQ Certification Scheme

The IAQ programs mentioned above are similar to Hong Kong’s IAQ Certification Scheme. The Scheme assigned guidelines values to IAQ parameters and created a voluntary program in which office and commercial buildings could become certified if IAQ parameter guidelines are met. Comparatively, the European Commission’s “Lowest concentration of interest” policy assigned critical values to over 100 volatile organic compounds above which the volatile organic compounds could cause people health problems in an indoor environment. In the same way, Texas created the Voluntary IAQ Guidelines for Texas Government Buildings. Both California’s occupational safety and health program and the US Occupational Safety and Health Act provide exposure limits for airborne contaminants in workplaces. Just as Hong Kong’s IAQ Objectives are supposed to be reviewed and updated periodically, the United States’ and California's exposure limits are updated as necessary to keep up with the most recent information about IAQ.

The IAQ programs also compare to Hong Kong's IAQ Certification Scheme in the fact that they promote awareness of IAQ. When the Certification Scheme is advertised for shopping malls and other office or commercial buildings, it is consequently publicizing the issue of IAQ and encouraging the building owners to take steps to improve the IAQ of their buildings. The European Commission's community information system, the distribution of information on indoor air pollutants and conduction of IAQ seminars by Texas' IAQ Program, and IAQ activities coordinated by the California Interagency Working Group are all examples of ways the programs spread awareness of IAQ. In addition, the education and training programs on IAQ established under the US Occupational Safety and Health Act and the IAQ events, training course, and information provided by the IAQ UK organization help to increase the public's knowledge of IAQ.

2.4. Review of Hong Kong's IAQ Management Programme

In 2011 the Audit Commission, a government department, conducted reviews of government initiatives intended to complete the tasks of the IAQ Management Programme. The Audit Commission reviewed the IAQ Management Programme's tasks and evaluated the initiatives taken by the Environment Bureau, the EPD, the Electrical and Mechanical Services Department, and the Architectural Services Department. The initiatives were evaluated to determine the progress of fulfilling the tasks of the IAQ Management Programme. Comments and recommendations were given by the Audit Commission to the previously mentioned government departments (Environment Bureau, EPD, Electrical and Mechanical Services Department, and Architectural Services Department) to improve the initiatives.

Recommendations for the four main tasks of the IAQ Management Programme as previously stated are discussed in the following sub-sections.

2.4.1. IAQ Information Centre

Though the IAQ Information Centre serves good intentions, the Audit Commission Review revealed that “only about one group visited the Centre every two days and less than one individual visited the Centre a day” (Audit Commission, 2011). A group visit to the IAQ Information Centre had on average, 29 people per group. Below shows Table 2.5 with the number of visitors to the IAQ Information Centre from 2007 – 2010.

Table 2.5: Visits to the IAQ Information Centre (2007 to 2010) (The Audit Commission, 2011)

Year	Group Visit		Number of Individual Visitors
	Number of Groups	Total Number of Visitors from Groups	
2007	179	4, 950	407
2008	117	3, 575	176
2009	123	3, 556	35
2010	116	3, 609	84
Total	535	15, 690	702

The Audit Commission considers the number of visits to the IAQ Information Centre unsatisfactory. A survey conducted as part of the 2006 Consultancy Study by the EPD showed that “only 27% of respondents heard about the IAQ Management Programme, only 13% of respondents heard about the IAQ Certification Scheme, only 19% of respondents considered that the promotion of public awareness of IAQ was adequate, and 81% of respondents preferred the mass media for obtaining information about improvement of IAQ" (The Audit Commission, 2011). Despite survey responses on respondents' preference for obtaining IAQ information, from 2007 – 2010 there were only three instances of IAQ advertisements in newspapers and none on television or radio. Overall, the Audit Commission saw a need for the EPD to increase efforts in promoting and educating IAQ to the public.

Educating the public on IAQ included teaching students and scheduling school visits. In 2001, control of the IAQ Information Centre operations and maintenance was signed to a contract service provider. Within the contract, the service provider was required to conduct a specified number of school visits. Looking through documents and old files, the Audit Commission found that from 2007 – 2010, the number of school visits completed by the IAQ Information Centre was significantly lower than the number specified in the contract. The number of contract-specified school visits compared to the number of completed school visits is shown in Table 2.6 below.

Table 2.6: Required and Completed School Visits by IAQ Information Centre (The Audit Commission, 2011)

Year	School Visits	
	Contract Requirement	Completed
2007 – 2008	20	0
2008 – 2009	50	25
2009 – 2010	40	18
2010 – 2011	22	42

The Audit Commission recommended the EPD supervise the contract service provider to ensure that contract requirements are fulfilled. In addition, recommendations that formal letters be sent to primary and secondary Hong Kong schools to schedule formal presentations on IAQ were made as the IAQ Information Centre could be used more effectively to promote IAQ awareness (The Audit Commission, 2011).

2.4.2. *Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places (GN)*

After observations and review of the *Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places* (GN), the Audit Commission noted that some aspects of the GN were unsatisfactory and had room for improvement. Compliance with the GN was voluntary and building managements or owners were not required to comply with the GN. The Audit Commission noted that the GN was valid only for office buildings and public places ventilated with MVAC systems. The Audit Commission recommended that the EPD include childcare centers and schools in the GN as well as the IAQ Objectives to protect the health of the youth. The Audit Commission also noted that the EPD had not created feedback mechanisms. There was nothing in place to see how many people adopted and followed the GN, or mechanisms to ask those who had not adopted the GN for their reasons for not doing so. For those who did follow the GN, there was no mechanism to ask for their opinions and comments on the improvement of the GN. Procedures to determine why buildings were not complying with the GN or procedures to determine the difficulty in complying with the GN for those that had adopted the GN were missing. The Audit Commission recommended that the EPD create and put in place mechanisms to obtain feedback on the GN.

Recommendations for improving the GN on how to monitor IAQ for offices and public places and making them more appealing for buildings to adopt them followed. The Audit Commission encouraged the EPD to increase the effectiveness of the IAQ Certification Scheme by investigating reasons for low participation and reminding participants to renew their IAQ certificates before the expiration dates. For buildings to renew their IAQ certification, the department filling out the certification report should ensure that there is (1) no change in the operation of the building that could harm the IAQ and (2) no alterations to the operation/maintenance of the building's MVAC system that could negatively affect the IAQ. The departments were also urged to assess the IAQ of public places, not just during weekdays, but also on weekends, when there is high occupancy in the buildings (Audit Commission, 2011). All of these recommendations were for the improvement of IAQ in all commercial buildings and public places in Hong Kong.

2.4.3. IAQ Certification Scheme

Critics have questioned the effectiveness of the Certification Scheme. Comments have been made that the simple, yet harsh, criteria for the parameters can backfire on the EPD's goal of informing and educating the general public about IAQ (Burnett, 2005). In 2005, John Burnett, a professor in the Department of Building Services Engineering at the Hong Kong Polytechnic University, commented, "The perception of many is that the pollutant levels as presented become 'standard' which, if exceeded, will lead to 'dire consequences'" (Burnett, 2005; Hong Kong Housing Authority, 2004). The Certification Scheme has caused a situation in which people believe that adverse health effects will result if the IAQ parameters were to exceed the 'standard'. An example of a pollutant commonly perceived to have dire consequences if its concentration exceeds the 'standard' is carbon dioxide (CO_2). Burnett explained how CO_2 is confusing in terms of its relevance in IAQ because he believes that CO_2 is not an important pollutant with respect to adverse health effects yet a building with no harmful pollutants can fail certification because the average CO_2 levels are greater than 1000 ppm. Pilot studies have shown that the complexity and cost of the evaluation for the certification would be a great deterrent (Burnett, 2005). Although there have been issues with the Certification Scheme, the average office IAQ has improved since the scheme's implementation (Hui et al., 2007).

Review of the IAQ Certification Scheme brought to light the inconsistencies in the certificate issuing bodies. There was a gray area in which measured values were 'equal to or less than' the standard value for 'Excellent' or 'Good' class. This gray area allowed certificate issuing bodies to issue excellent certificates rather than good certificates if measured values were "equal to" the standard value for Excellent or Good class. For example, if a certificate issuing body was measuring temperature and got a temperature of 25.5 °C, looking back at Table 2.2, it would be ambiguous as to whether 25.5 °C belonged in 'Excellent' or 'Good' class. Recommendations from the Audit Commission include clarifying the gray area between Excellent and Good class and including an 'equal to' value.

Given the number of the buildings in Hong Kong, the Audit Commission considered the number of buildings certified by 2010 to be low and unsatisfactory. In 2002, the Home Affairs Department of the Government of the HKSAR created a database of all the private buildings in Hong Kong including commercial, industrial, and residential. The disclaimer from the Home Affairs Department of the Government of the HKSAR states that the database is not 100% accurate and does not guarantee that every building has been taken into account but the database gives a rough estimate of 40, 070 privately owned buildings (Home Affairs Department of the Government of the HKSAR, 2002). Even though the estimation includes privately owned residential buildings, the number of certified buildings still seems to be significantly small in comparison considering how the number of public places is not included in the estimation. From 2003 – 2010, a total of 559 buildings were certified as either 'Excellent' or 'Good' class. Of the 550 buildings, 319 were office buildings and 240 were public places. At the end of 2010, there were 124 buildings certified as 'Excellent' class and 435 buildings certified as 'Good' class. Provided below in Table 2.7 is the number of certified buildings for each class from 2003 – 2010.

Table 2.7: Participation in the IAQ Certification Scheme from 2003-2010

(Audit Commission, 2011)

As of December 31st of the year	Type of Building			Certification Class		
	Office Building [#]	Public Place [#]	Total Buildings (office + public)	Excellent [#]	Good [#]	Total (Excellent + Good)
2003	26	1	27	2	25	27
2004	60	21	81	10	71	81
2005	61	69	130	11	119	130
2006	74	96	170	27	143	170
2007	171	92	263	42	221	263
2008	263	152	415	61	354	415
2009	312	211	523	99	424	523
2010	319	240	559	124	425	559

2.4.4. Hong Kong IAQ Objectives

More importantly, the Audit Commission noticed the Hong Kong IAQ Objectives have not been updated since they were established in 2003. The acceptable levels for the twelve parameters have not been reviewed and updated and no new parameters have been added. From 2006 – 2010, WHO has published three IAQ documents providing information valuable to adding airborne fungi as a new parameter to the IAQ Objectives. In addition, $PM_{2.5}$ is an important aspect of air quality and is currently being used as an indicator for poor outdoor air quality but has yet to be incorporated into IAQ parameters. The EPD has agreed to review the acceptable levels for the parameters in comparison to international standards and refer to published WHO guidelines to make recommendations on airborne fungi to the IAQ Management Group. As of the start of the year 2014, no updated IAQ Objectives have been published by the EPD.

2.5. Project Purpose, Goal & Objectives

Research on IAQ in Hong Kong has made much progress, but there are still additional studies to be performed. In particular, it is important to note that the latest research completed on people's views and experiences with IAQ in Hong Kong was released on March 19, 2010. For the study, 1,010 respondents were interviewed and the results were quite concerning. About 80% of the interviewees had suffered from SBS symptoms (Ipsos, 2010). Four in five of the respondents were living with illnesses linked to indoor air pollution, while one-third of respondents believed poor IAQ had negative effects on their health (Hong Kong Standard Newspapers Ltd., 2010). Reports of the study revealed that 90% of respondents were unsatisfied with the IAQ in Hong Kong and approximately 30% thought of the air quality as "bad" or "very bad" (Ipsos, 2010). The Hong Kong Audit Commission, a government department that evaluates other government departments and provides recommendations to improve efficiency and overall performance, set out to improve IAQ in response to the negative feedback from the surveys (Audit Commission, 2005).

This project seeks to study people's views on IAQ and evaluate the IAQ Management Programme tasks. Mainly, this project focused on the public awareness and effectiveness of the IAQ Certification Scheme, the status of the Hong Kong IAQ Objectives, and relevant IAQ technology. Project objectives included evaluating public opinion in certified and uncertified shopping malls and reviewing current Hong Kong IAQ Objectives as well as the latest technology relevant to IAQ.

3. Methodology

For this project, three objectives were completed. Objective 1 involved collecting the general public's opinion of IAQ in six certified and four uncertified shopping malls. Objective 2 involved the comparison between current Hong Kong IAQ Objectives and international IAQ guidelines. Objective 3 involved researching the latest technology in IAQ and providing brief summaries of each technology to be used as a resource to Business Environment Council Limited. For objective 1, questionnaires were answered by mall patrons and responses were compiled and analyzed using Microsoft Excel and SPSS Statistics 22 (IBM Corp., 2013). For objectives 2 and 3, extensive research was conducted. In the following sections, more in-depth procedures for completing each objective are described.

3.1. Objective 1: Surveying Shopping Malls and Data Analysis

The methodology of Objective 1 is divided into six sections. The first section discusses the mall selection process for distributing questionnaires. The second section explains the data entry process. Sections three through six describe the procedure of analyzing the data to compare the survey locations, the certification statuses, the certification classes, and the ten shopping malls.

3.1.1 Selecting Shopping Malls & Surveying

In order to do comparison between the general public's opinion of IAQ in certified and uncertified shopping malls, a sampling frame of patrons and employees within selected certified and uncertified shopping malls was chosen. A total of ten shopping malls were chosen within the three regions of Hong Kong: Kowloon, Hong Kong Island, and the New Territories. Lantau Island was considered to be part of the New Territories. The three regions of Hong Kong are shown in Figure 3.1 below.

Figure 3.1: Map of Three Regions in Hong Kong
Figure 3.1 is a derivative of "Hong Kong districts map", by Peter Fitzgerald, used under CC BY 3.0.

Four shopping malls were certified as 'Good' class and two shopping malls were certified as 'Excellent' class. The remaining four shopping malls were uncertified in the IAQ Certification Scheme. It is important to note that malls referred to as uncertified does not mean that they failed the IAQ certification but rather they have yet to go through the certification process. A 'Good' class, an 'Excellent' class, and an uncertified shopping mall were chosen in each of the three regions of Hong Kong. The malls were later modified to consist of five malls from Kowloon, two from Hong Kong Island, and three from the New Territories. There were only two malls that were in the 'Excellent' class in Hong Kong Island and surveying at these malls presented challenges that were unable to be overcome in the time frame of this project. Certified 'Good' and 'Excellent' shopping malls were chosen from the IAQ Information Centre website randomly. The uncertified shopping malls were chosen randomly from a map of Hong Kong regions. The shopping malls were checked against the list of certified premises available on the IAQ Information Centre website to ensure that they were uncertified. The location of the ten malls as well as their certification status is listed in Table 3.1 below.

Table 3.1: Certification Class and Locations of the Shopping Malls

Shopping Mall	Certification Status	Location
1	Excellent	New Territories
2	Excellent	Kowloon
3	Good	Kowloon
4	Good	Kowloon
5	Good	Hong Kong Island
6	Good	New Territories
7	Uncertified	Kowloon
8	Uncertified	New Territories
9	Uncertified	Kowloon
10	Uncertified	Hong Kong Island

The questionnaires were conducted from January 17, 2014 to February 15, 2014. Approximately fifty questionnaires were distributed at nine of the shopping malls and 100 questionnaires were distributed at Mall 3, totaling to 526 questionnaires. To check whether or not taking the survey inside or outside the mall had an effect on questionnaire data, 100 questionnaires were distributed at Mall 3; fifty questionnaires inside the mall and fifty outside the mall entrance. Generally, the questionnaires were conducted in the early afternoon and late evening during shopping mall peak hours from Wednesday through Saturday.

Through a series of questions designed to obtain perceptions on the IAQ, the general public answered questions providing their opinions on factors that affect the IAQ in the shopping mall they were in, such as odors in the air. The questionnaire also investigated how familiar the public was with the IAQ Certification Scheme and if the public thought that the IAQ in certified shopping malls was better than that of uncertified shopping malls.

Questionnaires were distributed outside of the malls' main entrance or outside an entrance with a lot of traffic flow. For some malls, questionnaires were distributed inside. The general public's opinion was determined through convenience sampling, "a technique in which a sample is drawn from that part of the population that is close to hand, readily available, or convenient" (Bhattacherjee, 2012). The general public was solicited to answer the questionnaire.

Obtaining formal permission from mall managements to survey inside their malls was difficult because the malls wanted to provide their patrons with the best shopping experience possible without outside interference. Another reason mall managements may not have been willing to give formal permission was because the malls might not have been fulfilling the IAQ Certification Objectives despite being certified.

3.1.2. Inputting Data & Calculating Weighted Scores

The raw data of each question in the questionnaire were the answers circled on the questionnaire prior to modification for data analysis. The raw data for each question were inputted into a Microsoft Excel file. The raw data of the first six "Air Quality" questions were also modified into weighted data that could be summed for an overall score for the shopping mall.

In order to calculate the weighted data, the first six "Air Quality" questions were designed on a scale of one to seven. The first six "Air Quality" questions are shown below in Figure 3.2.

Air Quality

1. How does the air quality in this shopping mall affect you?

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

2. How is the air flow in this shopping mall?

Too strong – 1	2	3	4 – Perfect	5	6	7 – No flow

3. How are the odours in the air of this shopping mall?

Very fragrant – 1	2	3	4 – No smell	5	6	7 – Very smelly

4. How is the humidity in this shopping mall?

Too humid – 1	2	3	4 – Perfect	5	6	7 – Too dry

5. How does the temperature in this shopping mall affect you?

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

6. How is the temperature in this shopping mall?

Too warm – 1	2	3	4 – Perfect	5	6	7 – Too cold

Figure 3.2: First Six "Air Quality" Questions in the Questionnaire

To determine the weighted data, "4" was given a value of "0" for neutral or no effect. For numbers that deviated away from "4", depending on whether the deviation correlated with a positive or negative response, a weighted value was given accordingly. For questions that had a positive response associated with "1" and a negative response associated with "7" ("Air Quality" questions 1 and 5), the values "3", "2", and "1" were weighted as "1", "2", and "3" respectively. The values "5", "6", and "7" were weighted as "-1", "-2", and "-3" respectively. For questions that had negative responses associated with "1" and "7" ("Air Quality" questions 2, 3, 4, and 6), the values "3" and "5" were weighted as "-1", the values "2" and "6" were weighted as "-2", and the values "1" and "7" were weighted as "-3". Figure 3.3 explains how to calculate weighted data for "Air Quality" questions 1-6.

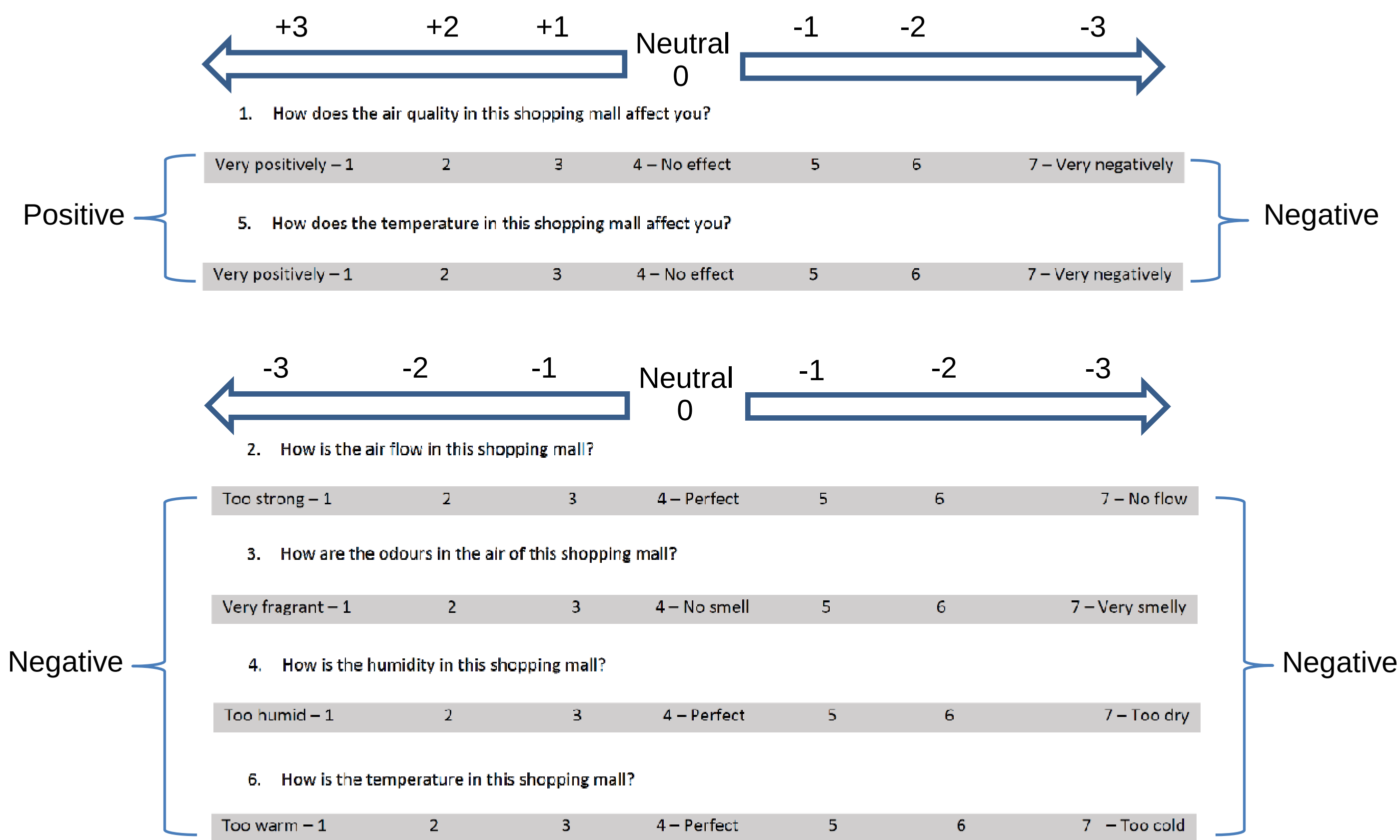
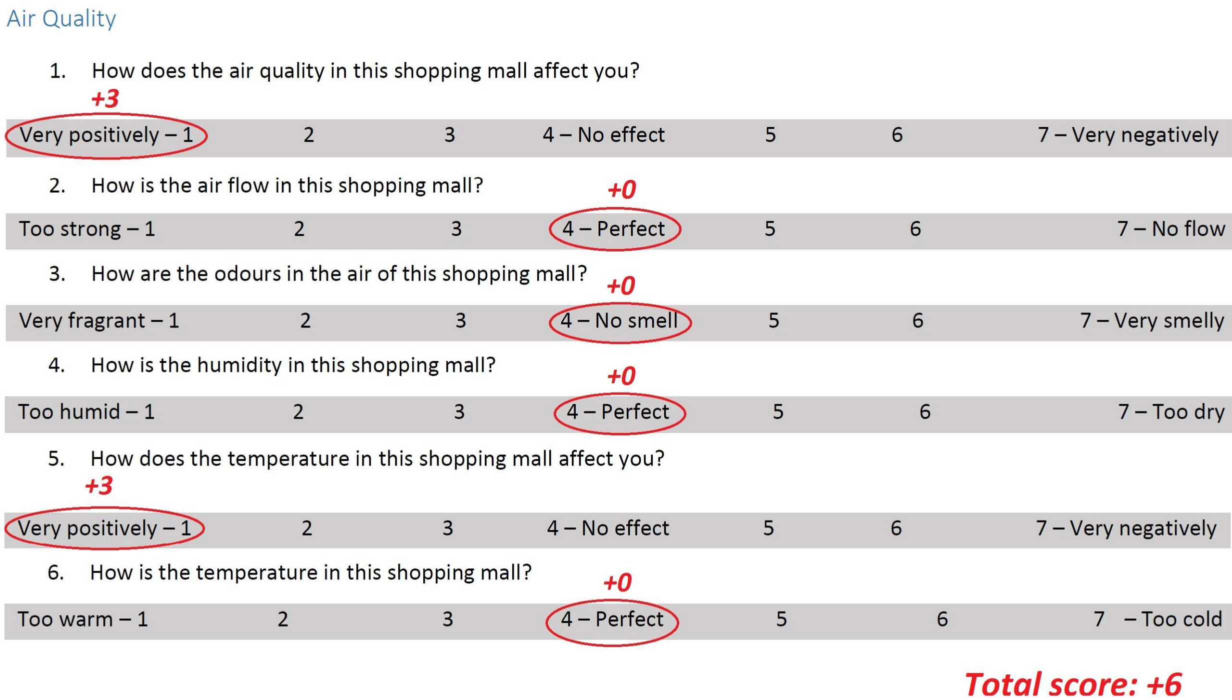


Figure 3.3: Calculating Weighted Scores of "Air Quality" Questions 1-6

The weighted data of the six "Air Quality" questions were totaled to a weighted-score sum. This way, the highest weighted-score sum a shopping mall could receive was a "6" and the lowest score a shopping mall could receive was "-18". Sample questionnaires of the highest score and lowest score are given in Figures 3.4 and 3.5. The weighted data were summed because this enables the "Air Quality" ordinal scale data to be treated as interval scale data and to give a quantitative measurement instead of a relative measurement of IAQ perception (Boone & Boone, 2012).



Air Quality

1. How does the air quality in this shopping mall affect you?

+3

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

2. How is the air flow in this shopping mall?

+0

Too strong – 1	2	3	4 – Perfect	5	6	7 – No flow

3. How are the odours in the air of this shopping mall?

+0

Very fragrant – 1	2	3	4 – No smell	5	6	7 – Very smelly

4. How is the humidity in this shopping mall?

+0

Too humid – 1	2	3	4 – Perfect	5	6	7 – Too dry

5. How does the temperature in this shopping mall affect you?

+3

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

6. How is the temperature in this shopping mall?

+0

Too warm – 1	2	3	4 – Perfect	5	6	7 – Too cold

Total score: +6

Figure 3.4: Sample Questionnaire of Best Weighted-Score Sum

Figure 3.5: Sample Questionnaire of Worst Weighted-Score Sum

3.1.3. Data Analysis: Comparing Survey Locations

To determine whether or not conducting questionnaires inside or outside of shopping malls affected the data, Mall 3 data were analyzed in SPSS Statistics 22 (IBM Corp., 2013). Fifty questionnaires were collected inside and outside of Mall 3 allowing a comparison between the two sets of questionnaires. The statistical tests used to determine whether surveying location affected data were independent-samples t-test, Mann-Whitney U test, and the chi-square test for association. These three tests determined if there was a statistical difference between data from the two survey locations – inside and outside. If a statistical difference was present then it can be concluded that conducting questionnaires inside and outside shopping malls mattered in terms of results. For all three of these tests, survey location was the independent variable which could be divided into two independent groups – inside and outside. The weighted-score sum from the first six “Air Quality” questions was the dependent variable for the independent-samples t-test and the Mann-Whitney U test. “Air Quality” questions 1-6, 10, and 11 from the questionnaire were each dependent variables in the Mann-Whitney U test. “Air Quality” questions 8 and 9 were each dependent variables in the chi-square test. The independent groups (inside and outside) were compared to each other through the three statistical tests using their respective dependent variables.

The independent groups, with respect to the dependent variable of the weighted-score sum, were analyzed with the independent-samples t-test if no assumptions were violated. According to Laerd Statistics, a website of statistics resources for students and academics, “[t]he independent-samples t-test is used to determine if a difference exists between the means of two independent groups on a continuous dependent variable” (Laerd Statistics, 2013c). Some important assumptions of the t-test are that there are no outliers in any of the groups and that each group’s data are normally distributed (Laerd Statistics, 2013c). Explanation of the t-test and outlier is located in Appendix C. The independent groups were checked to ensure that no t-test assumptions were violated before the dependent variable of the weighted-score sum was analyzed with the t-test. Results of the independent-samples t-test determined if questionnaires conducted inside and outside were statistically different based on the averages of the weighted-score sum of the questionnaires. If any of the t-test assumptions were violated, the Mann-Whitney U test was used to analyze the dependent variable of the weighted-score sum. The Mann-Whitney U test is used for ordinal or continuous data to determine whether there is a statistical difference between the medians of the independent groups. The Mann-Whitney U test has fewer restrictions and assumptions than the t-test (Lowry, 2013c). In addition to analyzing the dependent variable of the weighted-score sum, dependent variables “Air Quality” questions

1-6, 10, and 11 were also analyzed using the Mann-Whitney U test. Results of the Mann-Whitney U test also determined if questionnaires conducted inside and outside were statistically different but based on the median of the weighted-score sums of the questionnaires rather than the average in the t-test. “Air Quality” questions 8 and 9 were analyzed with the Chi-square test for association, which tests whether two nominal variables (survey location and either “Air Quality” question 8 or 9) are associated or independent (Laerd Statistics, 2013a). Results from the chi-square test for association determined if answers to “Air Quality” questions 8 and 9 were associated to the survey location or if the answers were independent of survey location. More detailed explanations of the statistical tests and terms used in the methodology are located in Appendix C.

3.1.4. Data Analysis: Comparing Certification Statuses

All the questionnaire data from every mall were analyzed to determine whether people could perceive a difference in IAQ between certified and uncertified shopping malls. The certification status was the independent variable divided into two independent groups – certified and uncertified. The independent-samples t-test, Mann-Whitney U test, and the chi-square test for association were again used to determine if there was a statistical difference between the public’s opinions of IAQ in uncertified and certified shopping malls. The dependent variables used in the three statistical tests remained the same as the previous section (3.1.3. Data Analysis: Comparing Survey Location).

3.1.5. Data Analysis: Comparing Certification Classes

To investigate the IAQ Certification Scheme further, the data were analyzed to determine whether there were statistical differences in questionnaire responses in regards to the certification classes. The three certification classes are ‘Excellent’ class, ‘Good’ class, and uncertified. The

One-way analysis of variation (ANOVA), a statistical test, was utilized to determine if the three certification classes of shopping malls differed in IAQ based on the public's opinion. Similar to the t-test used previously to compare survey locations and certification statuses, the one-way ANOVA determines whether there is a statistical difference among the means of the three independent groups (Laerd Statistics, 2013f). Results from ANOVA showed if there was a statistical difference between the public's opinions of the IAQ in the three certification classes of shopping malls based on the means of the weighted-score sum. The certification class was the independent variable with three independent groups – excellent, good, and uncertified. The dependent variable was again the weighted-score sum from the first six "Air Quality" questions from the questionnaire. ANOVA was valid if the independent variable, with respect to the dependent variable of the weighted-score sum, was confirmed to have satisfied the assumptions of ANOVA. The most important assumptions of ANOVA are that "[t]here are no outliers in any of the groups," "[e]ach group's data is normally distributed," and "[t]he groups have equal variances" (Laerd Statistics, 2013f). If none of the assumptions of ANOVA were violated, ANOVA was performed. Results from ANOVA showed if there was a statistical difference between the average weighted-score sum of the three certification classes. However, ANOVA is not capable of showing which two certification classes differed if there was statistical difference. To find which two certification classes differed, the Tukey's HSD test, a post-hoc test, was performed after ANOVA (Verial & Demand Media, n.d.). If the assumptions of ANOVA were violated, the Kruskal-Wallis test was conducted. According to Laerd Statistics, "the Kruskal-Wallis test is the non-parametric alternative to the one-way ANOVA and is used to determine whether there are any statistically significant differences between the distributions of three or more independent (unrelated) groups" (Laerd Statistics, 2013d). If the Kruskal-Wallis test showed a significant difference, a pairwise comparisons post-hoc test was performed to see which certification classes differed. “Air Quality” questions 1-6, 10, and 11 were analyzed using the Kruskal-Wallis test and, if applicable, the pairwise comparisons test showed which pair with the three independent groups statistically differed. “Air Quality” questions 8 and 9 were analyzed by the Chi-square test for association.

3.1.6. Data Analysis: Comparing the Ten Shopping Malls

The data were also analyzed to rank the malls based on people’s perception of IAQ. The mall was the independent variable divided into ten independent groups – Malls 1 through 10. The weighted-score sum, calculated for each questionnaire from each of the ten malls, was attempted to be analyzed with ANOVA and Tukey’s HSD test. If ANOVA and Tukey’s HSD test could not be used because assumptions were violated, the Kruskal-Wallis test and the pairwise comparisons test were used instead. Table 3.2 summarizes the tests used for each “Air Quality” question with respect to the analyzed independent variables.

“Air Quality” questions 7, 7a, 12, and 13 were analyzed in Excel by calculating percentages of each answer of each question with respect to all the surveys collected. “Air Quality” question 12a was analyzed in Excel by calculating the question’s arithmetic mean with respect to all the surveys collected. These questions were separate from the other analyses because these questions were used to gauge the public’s interest and knowledge in IAQ.

A summary of the independent variables and their respective independent groups used I the statistical tests are shown in Table 3.3. Pie charts and bar graphs were created in SPSS Statistics 22 to show the demographics of the respondents (IBM Corp., 2013). The arithmetic mean of the time spent in malls was calculated.

Table 3.2: Summary of Statistical Tests Used for Analysis of Independent Variables

	“Air Quality” Question	Independent Variable			
		Survey Location	**Certification Status**	**Certification Class**	**Mall**
		Statistical Tests			
Dependent Variable	**1**	Mann-Whitney U Test		Kruskal-Wallis Test & Pairwise Comparisons Post-Hoc Test	N/A
	2				
	3				
	4				
	5				
	6				
	Sum of Weighted Score of 1-6	Independent Samples t-Test; or Mann-Whitney U Test if t-Test assumptions were violated		ANOVA & Tukey's HSD Test; or Kruskal-Wallis Test & Pairwise Comparisons Post-Hoc Test if ANOVA assumptions were violated	
	7	N/A		N/A	
	7a				
	8	Chi-Square Test for Association		Chi-Square Test for Association	N/A
	9				
	10	Mann-Whitney U Test		Kruskal-Wallis Test & Pairwise Comparisons Post-Hoc Test	N/A
	11				
	12	N/A		N/A	
	12a				
	13				

Table 3.3: Summary of Analyzed Independent Variables and their Independent Groups

Independent Variable	Independent Groups
Survey Location	Inside, Outside
Certification Status	Certified, Uncertified
Certification Class	Excellent, Good, Uncertified
Mall	Mall 1, Mall 2, Mall 3,…, Mall 10

3.2. Objective 2: Researching IAQ Parameter Guidelines

To complete the comparison between Hong Kong's IAQ Objectives and the IAQ guidelines of other countries, research was done on the current IAQ Objectives used in Hong Kong. Nine of the twelve parameters in the IAQ Objectives were chosen to be researched excluding the three physical parameters: temperature (T), relative humidity (RH), and air movement. Each of the nine parameters (carbon dioxide, carbon monoxide, formaldehyde, ozone, total volatile organic compounds, radon, airborne bacteria count, nitrogen dioxide, and respirable suspended particulates) chosen were researched individually to find international guidelines. Recommended guidelines from five countries were selected to compare with Hong Kong's IAQ Objectives because of the countries' similar climate with Hong Kong or because of Hong Kong's past references to the country's IAQ policies. The five countries are Canada, Singapore, Malaysia, Australia, and China. A table was created for each of the nine parameters listing Hong Kong's guidelines and recommended guidelines from the five different countries. The tables allowed for an easy comparison between Hong Kong's IAQ Objectives and international guidelines for each parameter. The World Health Organization's (WHO) latest recommended guidelines were also included for each of the nine parameters unless the parameter was not included in WHO's most recent recommendations for assessing IAQ. Though, WHO is not a country, Hong Kong's current IAQ Objectives were derived from past WHO recommended guidelines so it is helpful to compare Hong Kong's IAQ Objectives to WHO's most recently recommended IAQ guidelines. Comparisons between the international guidelines and current Hong Kong IAQ Objectives were made to determine where Hong Kong stood in comparison. From the comparisons, Hong Kong's IAQ Objectives were considered to be too low, too high, or on par with either WHO or internationally recommended guidelines. Research was also conducted on international airborne fungi guidelines because airborne fungi was promised to be added as an additional parameter in the next revision of Hong Kong's IAQ Objectives. In total, there were ten parameters compared.

3.3. Objective 3: Researching IAQ Technology

Based on email communication with mall management offices, it was determined that some malls have installed carbon dioxide detectors to control ventilation (M. Tung, personal communication, January 20, 2014). From this information, IAQ detectors capable of controlling ventilation systems were looked into to determine if more efficient and accurate detectors were available (Fantech Intelligent Ventilation, 2009; Honeywell Analytics, 2012a; Lennox International Inc., 2014; United Technologies Corporation, 2013). More research was done in regards to new technology in MVAC systems and filtration methods. Research was focused on technology that could replace or be incorporated into already installed MVAC systems (IEQ Global, 2013c; PeakPureAir, 2013; White, 2009). IAQ technology providers such as Honeywell were looked into to determine the approximate costs of the technology found (Honeywell Analytics, 2012b). Research was done on different technological advances to make Hong Kong's MVAC systems more efficient or upgraded. Technologies were compared to determine what would be the most valuable to Hong Kong (Siegel & Zaatari, 2003; White, 2009). Enhanced Media Filtration (EMF) filters, photocatalytic oxidation, and the Honeywell IAQPoint2 were determined to be beneficial technologies for Hong Kong, worth looking into. Research was done on the technologies and a list of questions meant to drive more thorough research was developed (Environmental Energy Technologies Division, 2014; Honeywell, 2012; HubPages, 2014; IEQ Global, 2013b). The questions included, "how often do EMF filters need to be replaced compared to High Efficiency Particulate Arresting (HEPA) filters?" and "is photocatalytic oxidation able to be used inside of MVAC systems?". HEPA filters were recommended by the Hong Kong government at the establishment of IAQ Certification Scheme and are most commonly used in MVAC systems (The Government of the HKSAR IAQ Management Group, 2003b). More research was conducted in order to answer the questions that came up during the previous research (Destaillats et al, 2012; Healthy Air, 2014; Honeywell, 2012). Finally, further research on information that could not be found was suggested for the EPD to look into, so that the EPD could conclude if any of these technologies would be of value to Hong Kong buildings.

4. Results and Discussion / Analysis

4.1. Questionnaire Results

The questionnaire results are divided into six sections. The first section discusses the demographics of the questionnaires. The second section compares survey location to determine whether surveying inside or outside statistically affected the data. The third section compares certification status to discover whether there were statistical differences in IAQ between certified and uncertified malls based on people's perceptions. The fourth section compares the certification classes to explore whether people could notice differences in IAQ among the 'Excellent', 'Good', and uncertified class malls. The fifth section compares each of the ten malls to determine which mall had the best IAQ based on the weighted-score sum. The sixth section analyzed "Air Quality" questions 7, 7a, 12, 12a, and 13.

4.1.1. Demographics of Samples

Five-hundred twenty-six (526) questionnaires were collected at the ten malls. A majority of the questionnaires (79.47%) were collected outside the malls, while 20.58% were collected inside the malls. Figure 4.1 shows how many questionnaires were collected at each mall, and

Figure 4.2 shows the percentages of surveying inside versus outside the malls. The goal was to collect 100 questionnaires at Mall 3, and 50 questionnaires at each of the other malls. Some malls had a little more or less than 50 questionnaires due to human error. Not all 50 questionnaires were collected at Mall 2 because surveying at Mall 2 proved to be challenging. Permission was not given to survey inside Mall 2, and mall security did not allow surveying near the mall's exits. The streets surrounding Mall 2 were also very inconvenient for surveying because they were very narrow and congested resulting in 25 questionnaires being collected.

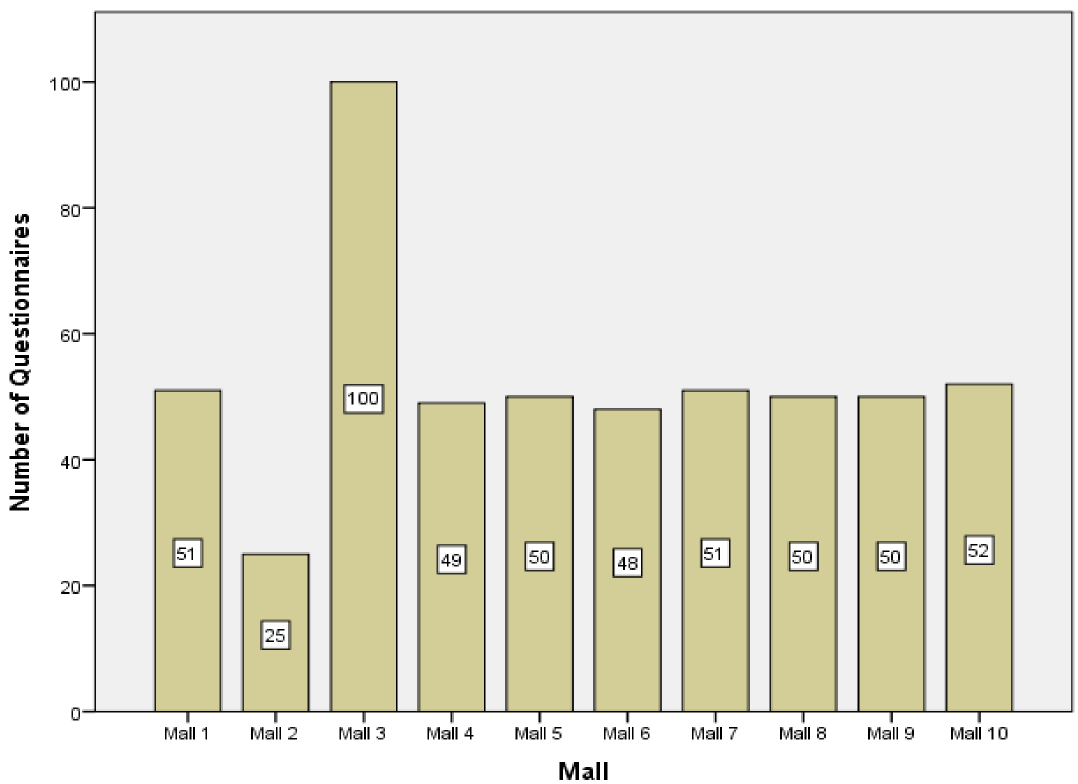


Figure 4.1: Number of Questionnaires Collected at Each Mall

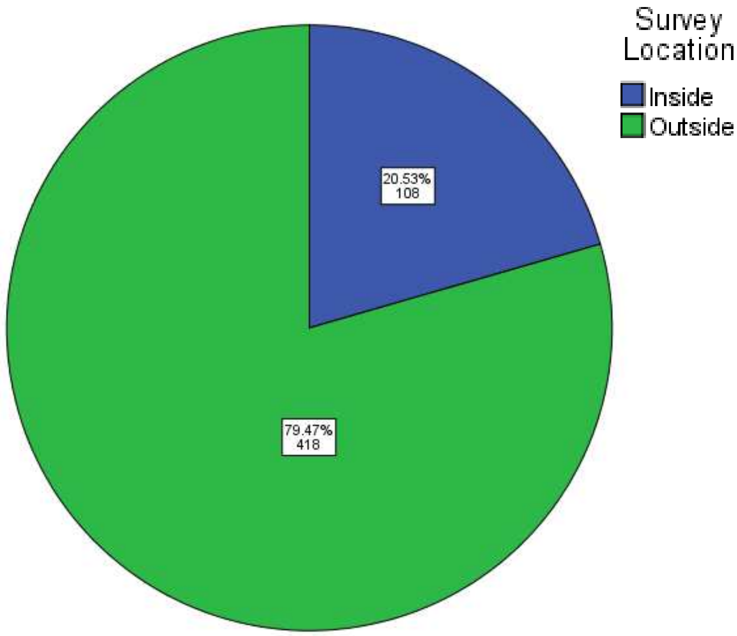


Figure 4.2: Survey Location Demographic

There were more responses from females and younger people than from males and older people, respectively. Regarding gender, 54.30% of questionnaire respondents were female and 45.70% were male, as seen in Figure 4.3. Respondents under the age of 21 represented 50.38% of the questionnaire total. Those in the age group of 21-35 years of age represented 40.08%, 36-45 years of age represented 4.58%, 46-64 years of age represented 4.58%, and aged 65 and over represented 0.28%. Figure 4.4 illustrates the age demographic, and Figure 4.5 shows the age and gender demographics together. Based on anecdotal stories from respondents, malls tended to be places where young people particularly high school and university students, especially female students, convene for recreation, so most respondents were under the age of 36 and female. Also, females and younger people under the age of 36 were generally more willing to stop to fill out the questionnaires. People over the age of 35 were less likely to stop to fill out the questionnaire because they were more in a hurry and/or had children with them who were unwilling to stop. There was not much response from those aged 65 and older because the elderly generally did not go to malls often. The average time people spent in the shopping malls was 86.30 minutes with a standard deviation of 87.62, and the median was 60 minutes.

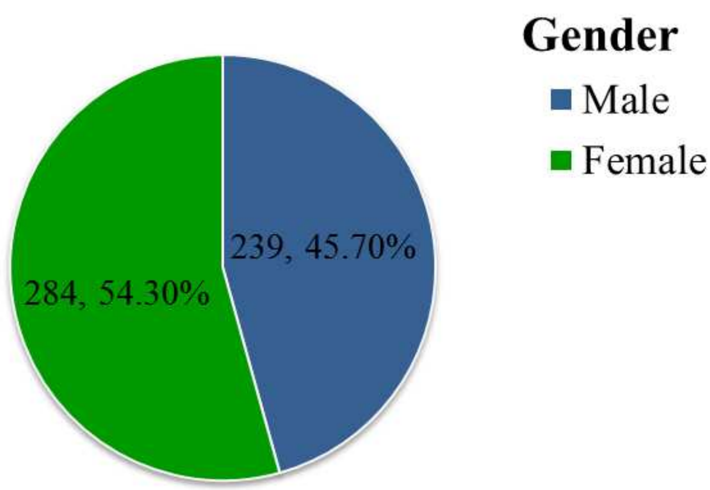


Figure 4.3: Gender Demographic

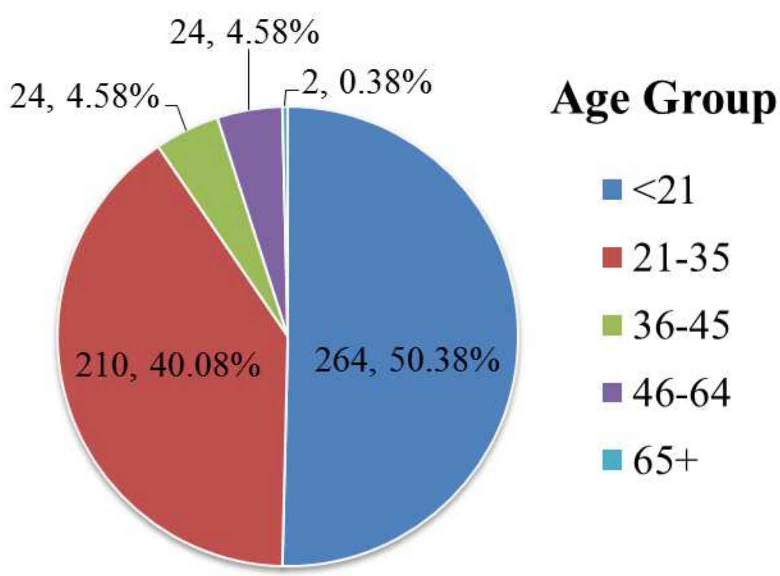


Figure 4.4: Age Demographic

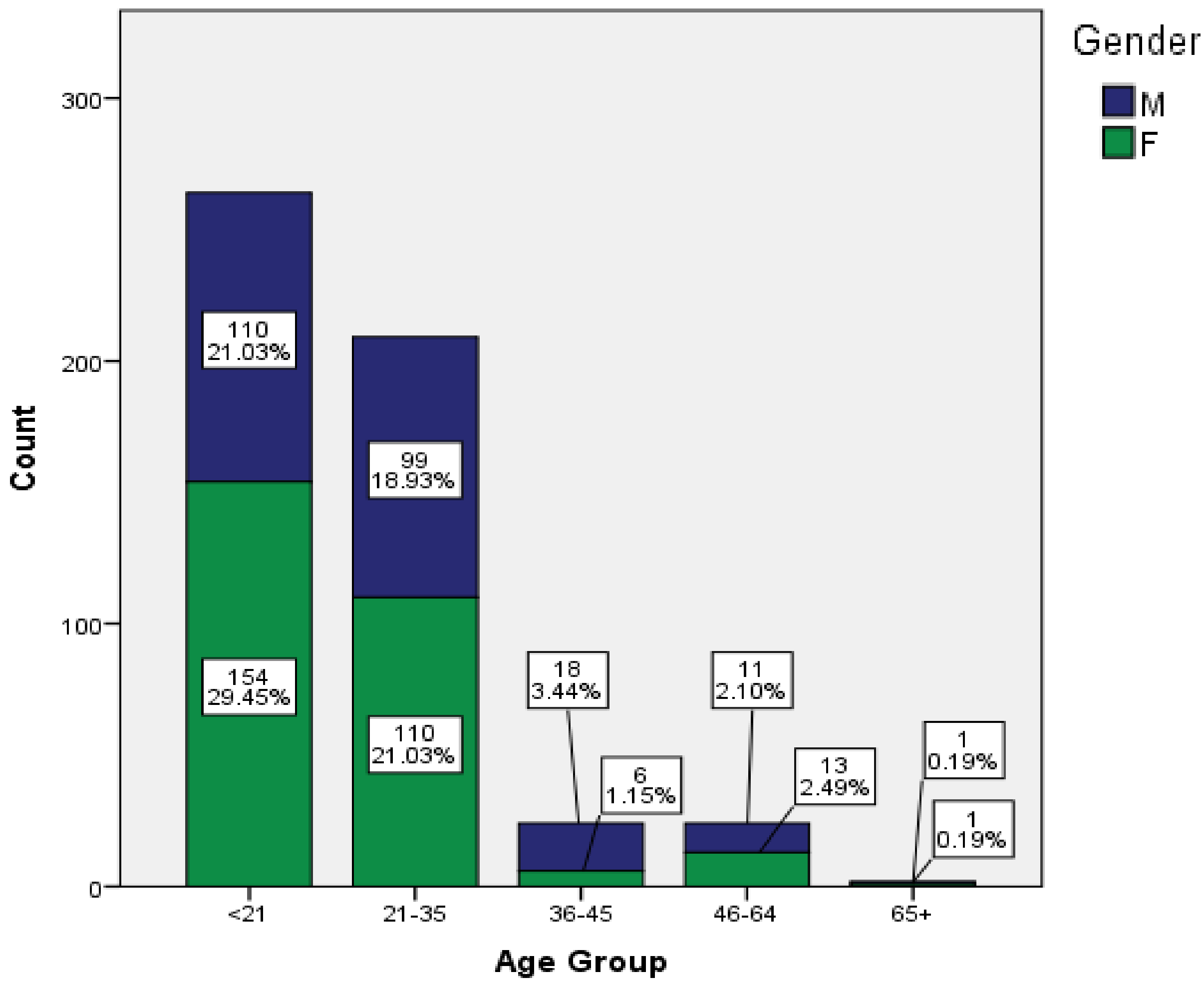


Figure 4.5: Age and Gender Demographics

There were more Hong Kong residents surveyed than tourists. Of those who responded, 21.61% were tourists and 78.39% were residents. Many tourists came from the United States (27.45%), China (22.55%), United Kingdom (7.84%), Taiwan (6.86%), and Australia (5.88%). Figure 4.6 illustrates the residency demographic, and Figure 4.7 shows which countries the tourists were from.

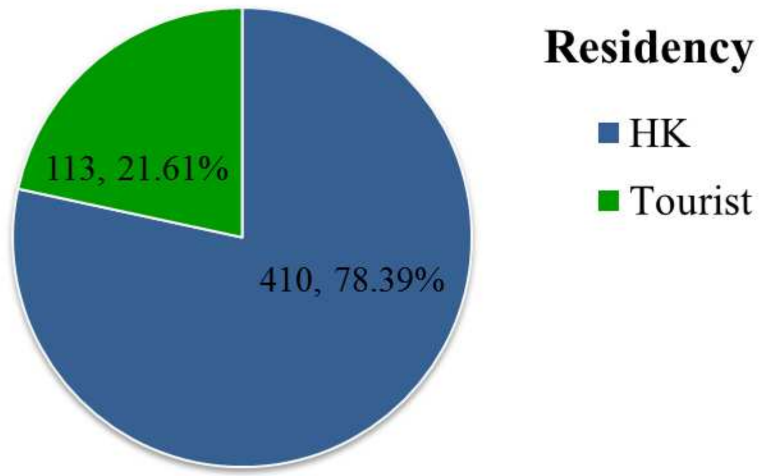


Figure 4.6: Residency Demographic

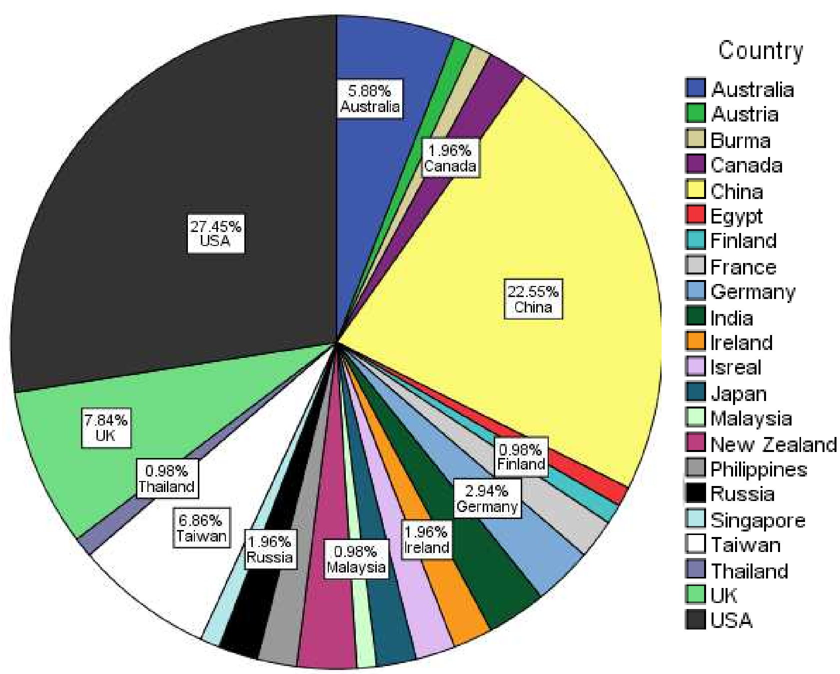


Figure 4.7: Tourist's Country Demographic

4.1.2. Comparing Survey Location – Inside and Outside

Since most of the data collected were from surveying outside, it was important to determine if the location of surveying (inside or outside of the mall) statistically affected the data. Mall 3 data was used to analyze whether or not a difference in data results occurred from surveying inside versus outside the mall. The first step was to check whether the independent-samples t-test could be used with the weighted-score sum. This was done by checking whether or not the data violated the assumptions of the t-test, such as the data do not contain outliers (Laerd Statistics, 2014c). To check, a boxplot of the sum of the weighted scores with respect to survey location was created, as seen in Figure 4.8. According to Figure 4.8, there were three outliers in the data. Therefore, the t-test could not be used and the Mann-Whitney U test was used instead.

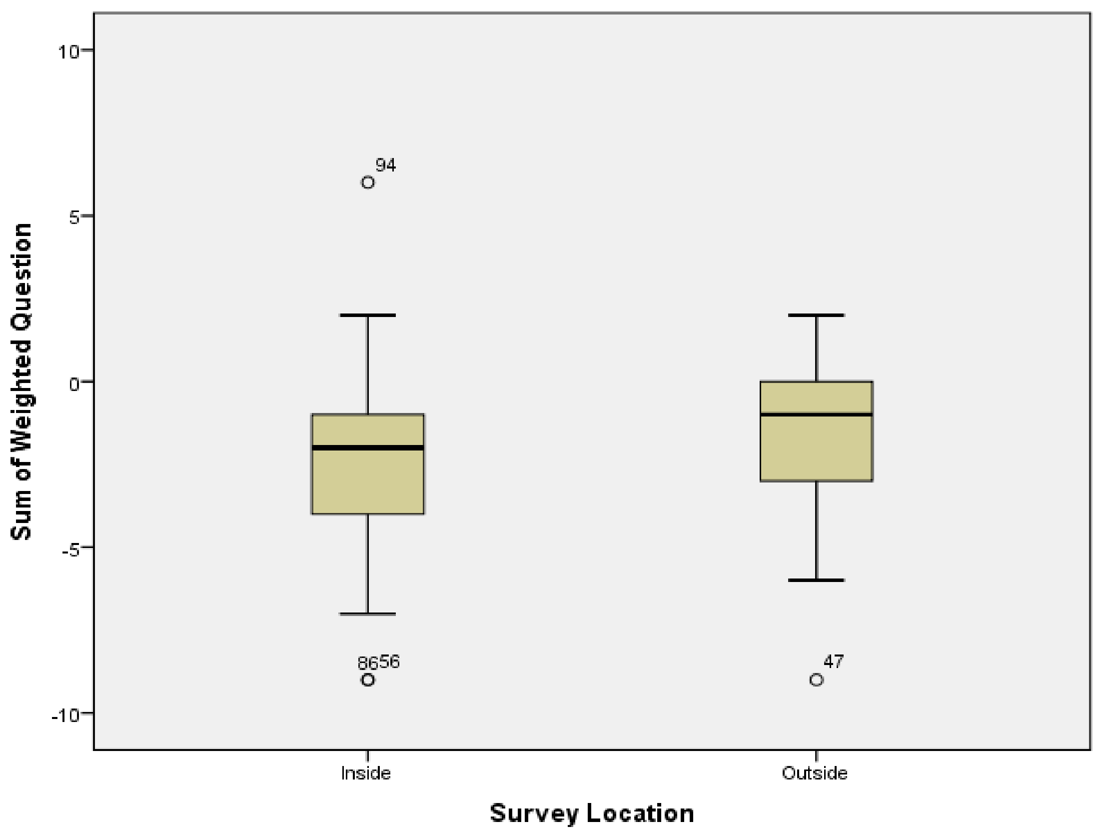


Figure 4.8: Boxplot of the Sum of Weighted Scores and Survey Location

The weighted-scores sum and "Air Quality" questions 1-6, 10 and 11 were analyzed with the Mann-Whitney U test. The Mann-Whitney U test gives a Mann-Whitney test statistic (U) value. The U value is converted into a z-score (z), and in turn a p-value (Graham, 2011). A significance level (α) of 0.05 was used for all statistical tests. This means that if the test result gives a p-value less than 0.05, then there is a statistical difference between the groups (e.g. inside and outside). Definitions of statistical terms, such as significance level and p-value, are located in Appendix C. The test results and p-values (p) of each question are located in Table 4.1, and medians of the raw data of "Air Quality" questions 1-6, 10, and 11 and the weighted-score sum are located in Table 4.2. In the tables and figures, "AQ" is an abbreviation for "Air Quality" question; for example "AQ1 raw" means "Air Quality" question 1 before being weighted. Also, "Sum of Weighted Quest." represents the weighted-score sum. Before a conclusion can be made regarding the medians of the raw data of "Air Quality" questions 1-6, 10, and 11 and the weighted-score sum, the distributions of the data were checked if they violated a critical assumption of the Mann-Whitney U test. The critical assumption is that the two distributions of the independent groups (survey locations inside and outside) have the same or similar shape (Laerd Statistics, 2013e). Distribution graphs of the questionnaire data with respect to survey location were created, as seen in Figures 4.9 to 4.17**.** As assessed by visual inspection, the distributions of the questions for inside and outside were similar. The median scores of "Air quality" question 1, U=13475, z=0.747, p=0.455; question 2, U=1093, z=-1.139, p=0.255; question 3, U=1275, z=0.190, p=0.849; question 4, U=1229, z=-0.156, p=0.876; question 5, U=1157.5, z=-0.677, p=0.498; question 6,U=1352.5, z=0.756, p=0.450; question 10, U=1141, z=-0.788, p=0.431; and the weighted-score sum, U=1349, z=0.690, p=0.490 were not statistically different between outside and inside. The score for "Air Quality" question 11 was statistically different between inside (Median (*Mdn*)=4.00) and outside (*Mdn*=3.00), U=828, z=-2.848, p=0.004. Since none of the p values from the statistical tests was less than 0.05, there was no statistical difference between data collected inside and outside the mall. The U and z values also have a critical value to show if there is a statistical difference but for this project, the focus is on p value. These results show that surveying inside or outside did not statistically affect questionnaire data, except for question 11.

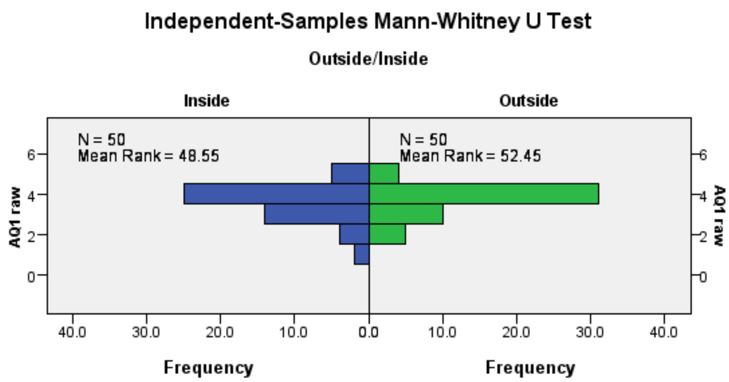
Table 4.1: Mann-Whitney U Test Results for Survey Location

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of AQ1 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.455	Retain the null hypothesis.
2	The distribution of AQ2 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.255	Retain the null hypothesis.
3	The distribution of AQ3 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.849	Retain the null hypothesis.
4	The distribution of AQ4 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.876	Retain the null hypothesis.
5	The distribution of AQ5 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.498	Retain the null hypothesis.
6	The distribution of AQ6 raw is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.450	Retain the null hypothesis.
7	The distribution of AQ10 is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.431	Retain the null hypothesis.
8	The distribution of AQ11 is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.004	Reject the null hypothesis.
9	The distribution of Sum of weighted quest. is the same across categories of Outside/Inside.	Independent-Samples Mann-Whitney U Test	.490	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

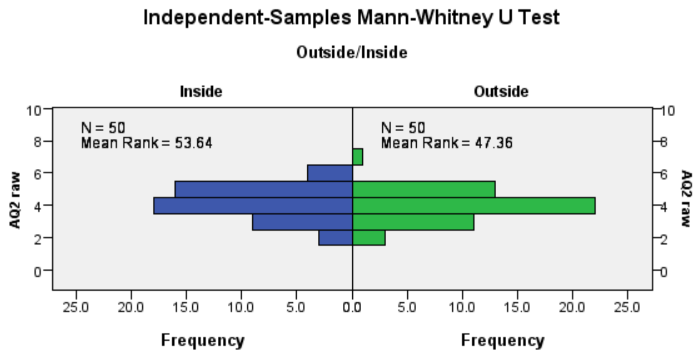
Table 4.2: Median of Dependent Variables with Respect to Survey Location

Outside/Inside		AQ1 raw	AQ2 raw	AQ3 raw	AQ4 raw	AQ5 raw	AQ6 raw	AQ10	AQ11	Sum of weighted quest.
Inside	N	50	50	50	50	50	50	50	50	50
	Median	4.00	4.00	4.00	4.00	4.00	3.50	4.00	4.00	-2.00
Outside	N	50	50	50	50	50	50	50	49	50
	Median	4.00	4.00	4.00	4.00	4.00	4.00	3.50	3.00	-1.00
Total	N	100	100	100	100	100	100	100	99	100
	Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	-2.00



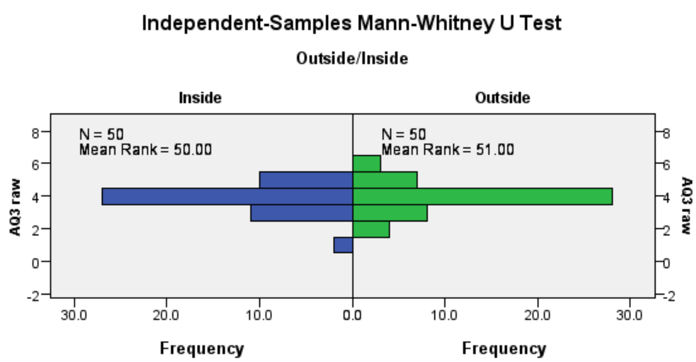
Total N	100
Mann-Whitney U	1,347.500
Wilcoxon W	2,622.500
Test Statistic	1,347.500
Standard Error	130.485
Standardized Test Statistic	.747
Asymptotic Sig. (2-sided test)	.455

Figure 4.9: Results for “Air Quality” Question 1 with Respect to Survey Location



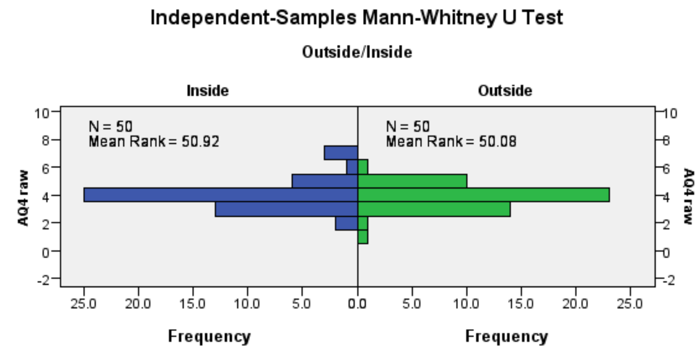
Total N	100
Mann-Whitney U	1,093.000
Wilcoxon W	2,368.000
Test Statistic	1,093.000
Standard Error	137.875
Standardized Test Statistic	-1.139
Asymptotic Sig. (2-sided test)	.255

Figure 4.10: Results for "Air Quality" Question 2 with Respect to Survey Location



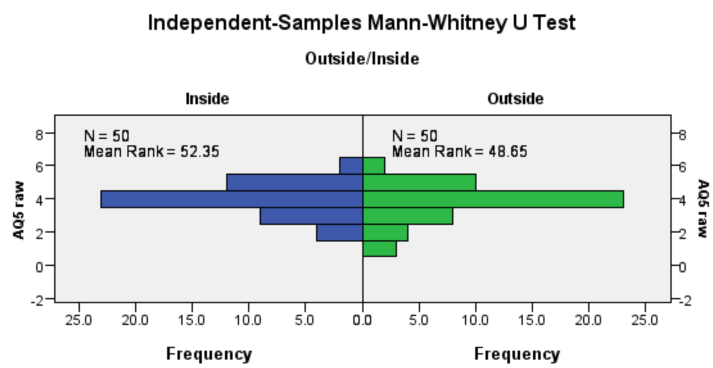
Total N	100
Mann-Whitney U	1,275.000
Wilcoxon W	2,550.000
Test Statistic	1,275.000
Standard Error	131.502
Standardized Test Statistic	.190
Asymptotic Sig. (2-sided test)	.849

Figure 4.11: Results for "Air Quality" Question 3 with Respect to Survey Location



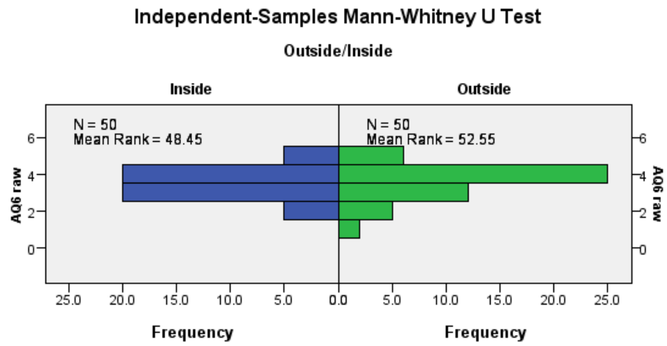
Total N	100
Mann-Whitney U	1,229.000
Wilcoxon W	2,504.000
Test Statistic	1,229.000
Standard Error	134.962
Standardized Test Statistic	-.156
Asymptotic Sig. (2-sided test)	.876

Figure 4.12: Results for “Air Quality” Question 4 with Respect to Survey Location



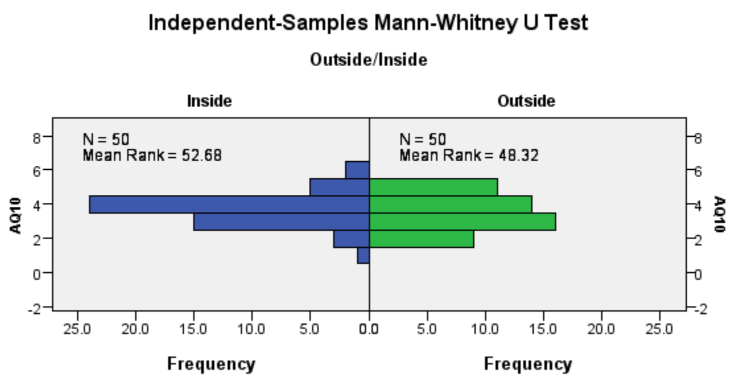
Total N	100
Mann-Whitney U	1,157.500
Wilcoxon W	2,432.500
Test Statistic	1,157.500
Standard Error	136.584
Standardized Test Statistic	-.677
Asymptotic Sig. (2-sided test)	.498

Figure 4.13: Results for “Air Quality” Question 5 with Respect to Survey Location



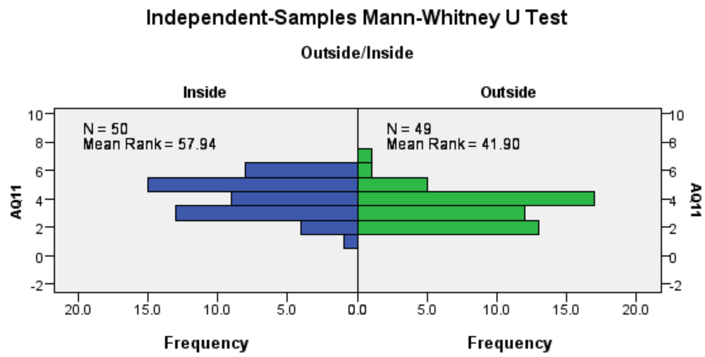
Total N	100
Mann-Whitney U	1,352.500
Wilcoxon W	2,627.500
Test Statistic	1,352.500
Standard Error	135.600
Standardized Test Statistic	.756
Asymptotic Sig. (2-sided test)	.450

Figure 4.14: Results for "Air Quality" Question 6 with Respect to Survey Location



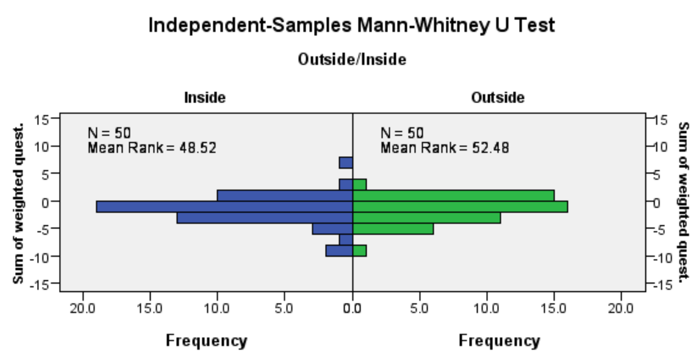
Total N	100
Mann-Whitney U	1,141.000
Wilcoxon W	2,416.000
Test Statistic	1,141.000
Standard Error	138.345
Standardized Test Statistic	-.788
Asymptotic Sig. (2-sided test)	.431

Figure 4.15: Results for "Air Quality" Question 10 with Respect to Survey Location



Total N	99
Mann-Whitney U	828.000
Wilcoxon W	2,053.000
Test Statistic	828.000
Standard Error	139.402
Standardized Test Statistic	-2.848
Asymptotic Sig. (2-sided test)	.004

Figure 4.16: Results for "Air Quality" Question 11 with Respect to Survey Location



Total N	100
Mann-Whitney U	1,349.000
Wilcoxon W	2,624.000
Test Statistic	1,349.000
Standard Error	143.499
Standardized Test Statistic	.690
Asymptotic Sig. (2-sided test)	.490

Figure 4.17: Results for the Sum of the Weighted Scores with Respect to Survey Location

To analyze "Air Quality" questions 8 and 9, cross tabulations of their data were made and the chi-square statistical test was conducted. The results for question 8 are located in Tables 4.3 and 4.4, and the results for question 9 are located in Table 4.5 and 4.6.

Table 4.3: Cross Tabulation of "Air Quality" Question 8 and Survey Location

			AQ8		
			Better	Worse	Total
Outside/Inside	Inside	Count	1	0	1
		Expected Count	.3	.8	1.0
		% within Outside/Inside	100.0%	0.0%	100.0%
		% within AQ8	100.0%	0.0%	25.0%
		% of Total	25.0%	0.0%	25.0%
	Outside	Count	0	3	3
		Expected Count	.8	2.3	3.0
		% within Outside/Inside	0.0%	100.0%	100.0%
		% within AQ8	0.0%	100.0%	75.0%
		% of Total	0.0%	75.0%	75.0%
Total		Count	1	3	4
		Expected Count	1.0	3.0	4.0
		% within Outside/Inside	25.0%	75.0%	100.0%
		% within AQ8	100.0%	100.0%	100.0%
		% of Total	25.0%	75.0%	100.0%

Table 4.4: Chi-Square Test of "Air Quality" Question 8 with Respect to Survey Location

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.000	1	.046		
Continuity Correction	.444	1	.505		
Likelihood Ratio	4.499	1	.034		
Fisher's Exact Test				.250	.250
N of Valid Cases	4				

Table 4.5: Cross Tabulation of "Air Quality" Question 9 and Survey Location

			AQ9			Total
			Yes	No	Don't Know	
Outside/Inside	Inside	Count	33	13	4	50
		Expected Count	35.0	11.5	3.5	50.0
		% within Outside/Inside	66.0%	26.0%	8.0%	100.0%
		% within AQ9	47.1%	56.5%	57.1%	50.0%
		% of Total	33.0%	13.0%	4.0%	50.0%
	Outside	Count	37	10	3	50
		Expected Count	35.0	11.5	3.5	50.0
		% within Outside/Inside	74.0%	20.0%	6.0%	100.0%
		% within AQ9	52.9%	43.5%	42.9%	50.0%
		% of Total	37.0%	10.0%	3.0%	50.0%
Total		Count	70	23	7	100
		Expected Count	70.0	23.0	7.0	100.0
		% within Outside/Inside	70.0%	23.0%	7.0%	100.0%
		% within AQ9	100.0%	100.0%	100.0%	100.0%
		% of Total	70.0%	23.0%	7.0%	100.0%

2 cells (33.3%) have expected count less than 5. The minimum expected count is 3.50.

Table 4.6: Chi-Square Test of "Air Quality" Question 9 with Respect to Survey Location

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.763	2	.683
Likelihood Ratio	.764	2	.682
N of Valid Cases	100		

The results in Tables 4.3 and 4.5 showed that the data for both questions 8 and 9 violated a condition for using the chi-square test. The violated condition was that “no more that 20% of the expected counts are less than 5 and all individual expected counts are 1 or greater” (Weaver, 2013). All of the expected counts for question 8 were less than five, and 33.3% of the expected counts for question 9 were less than five. An alternative method to analyze questions 8 and 9 was to conduct bootstrapping, which “is a computer-based method for assigning measures of accuracy to sample estimates” and “generate[s] an estimate of the sampling distribution of almost any statistic” (Cross Validated, 2012; Varian, 2005). Bootstrapping is beyond the capabilities of this project team because it involves computer coding, so no further analysis was conducted on questions 8 and 9 (Varian, 2005).

Analyzing Mall 3 data revealed that for “Air Quality” questions 1-6 and 10 and the weighted-score sum there was no statistical difference in surveying indoors and outdoors. However, for “Air Quality” question 11, which is rating the outdoor air quality, there was a statistical difference in conducting questionnaires inside and outside the mall. Analysis of “Air Quality” questions 8 and 9 could not be performed because of there was not enough data to satisfy the assumptions of the chi-square test.

4.1.3. Comparing Certification Status – Certified and Not Yet Certified

Objective 1 is compare the general public’s opinion of IAQ in certified and uncertified malls. To accomplish the objective, all 526 questionnaires from the ten malls, separated by certification status – certified and uncertified, were analyzed to determine whether people can distinguish the difference in IAQ in certified and uncertified malls. The first dependent variable to be analyzed was the sum of the weighted scores. The sum was checked if it violated the assumptions of the independent t-test. Figure 4.18 showed that the sum had five outliers, thereby violating the t-test assumption of having no outlier data. Since the t-test could not be conducted, the Mann-Whitney U test was used to analyze the sum instead.

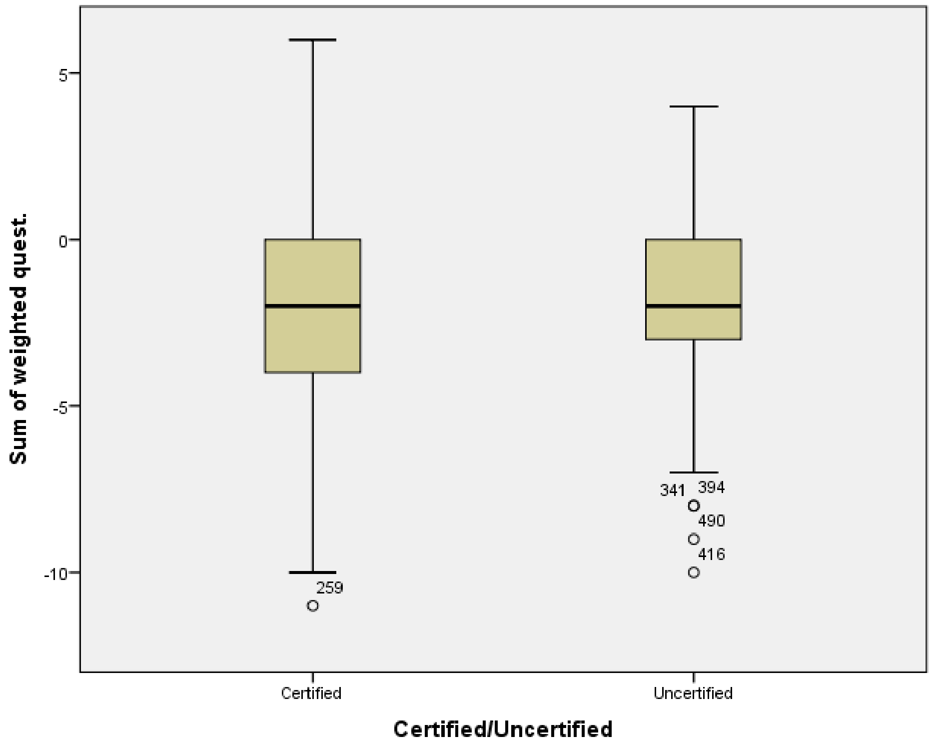


Figure 4.18: Boxplot of the Sum of Weighted Scores and Certification Status

The sum of the weighted scores and “Air Quality” questions 1-6, 10, and 11 were analyzed with the Mann-Whitney U test. The test results for each question are located in Table 4.7, and the medians of the data are located in Table 4.8. The distributions of the questions were examined if they violated they assumption that the distributions of the two independent groups (certified and uncertified) have the same or similar shape (Laerd Statistics, 2013e). The distributions of the questions are located in Figures 4.19 to 4.27. By visual inspection, the distributions of “Air Quality” questions 1-6 and 10 and the weighted-score sum for uncertified and certified were determined to be similar, but the distribution for “Air Quality” question 11 for uncertified and certified were determined to be unlike. This meant that the results of the Mann-Whitney U test for question 11 could not use the median but rather the mean ranks to determine whether there was a statistical difference between the certification status groups (Laerd Statistics, 2013e). Mean ranks are explained in Appendix C.

Table 4.7: Mann-Whitney U Test Results for Certification Status

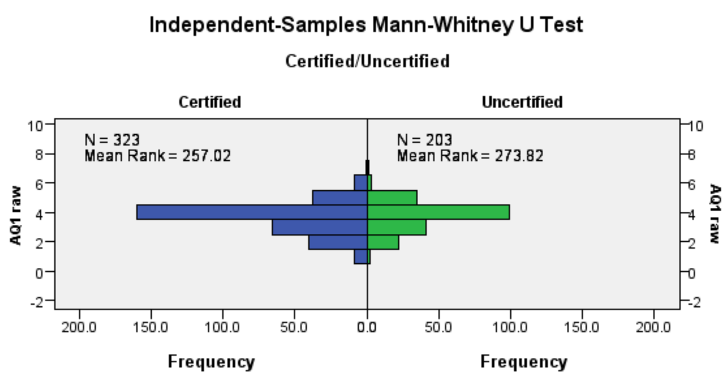
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of AQ1 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.185	Retain the null hypothesis.
2	The distribution of AQ2 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.079	Retain the null hypothesis.
3	The distribution of AQ3 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.691	Retain the null hypothesis.
4	The distribution of AQ4 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.990	Retain the null hypothesis.
5	The distribution of AQ5 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.838	Retain the null hypothesis.
6	The distribution of AQ6 raw is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.844	Retain the null hypothesis.
7	The distribution of AQ10 is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.598	Retain the null hypothesis.
8	The distribution of AQ11 is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.003	Reject the null hypothesis.
9	The distribution of Sum of weighted quest. is the same across categories of Certified/Uncertified.	Independent-Samples Mann-Whitney U Test	.241	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

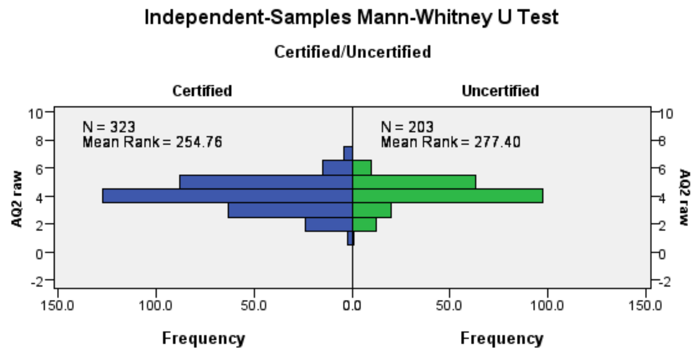
Table 4.8: Median of Dependent Variables with Respect to Certification Status

Certified/Uncertified	AQ1 raw	AQ2 raw	AQ3 raw	AQ4 raw	AQ5 raw	AQ6 raw	AQ10	AQ11	Sum of weighted quest.
Certified	4.00	4.00	4.00	4.00	4.00	4.00	3.50	4.00	-2.00
Uncertified	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00	-2.00
Total	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00	-2.00



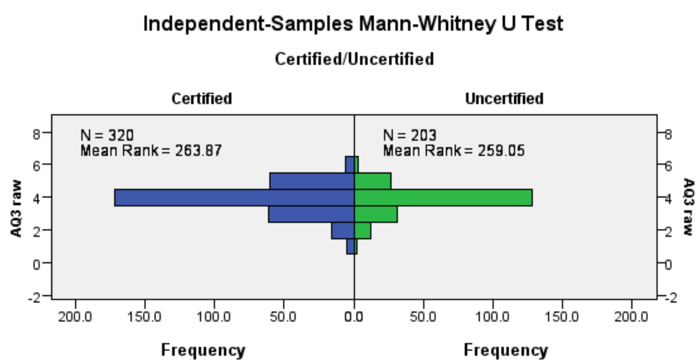
Total N	526
Mann-Whitney U	34,879.000
Wilcoxon W	55,585.000
Test Statistic	34,879.000
Standard Error	1,580.853
Standardized Test Statistic	1.325
Asymptotic Sig. (2-sided test)	.185

Figure 4.19: Results for “Air Quality” Question 1 with Respect to Certification Status



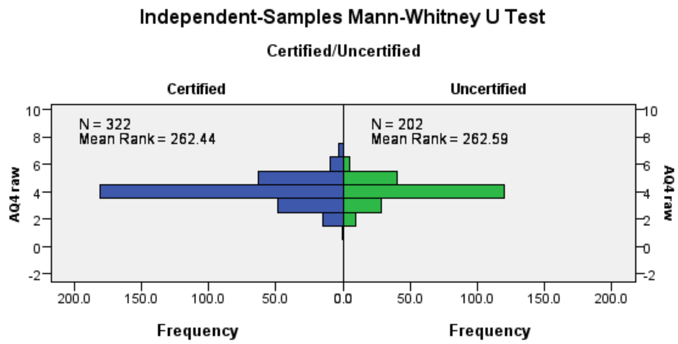
Total N	526
Mann-Whitney U	35,606.500
Wilcoxon W	56,312.500
Test Statistic	35,606.500
Standard Error	1,605.154
Standardized Test Statistic	1.758
Asymptotic Sig. (2-sided test)	.079

Figure 4.20: Results for “Air Quality” Question 2 with Respect to Certification Status



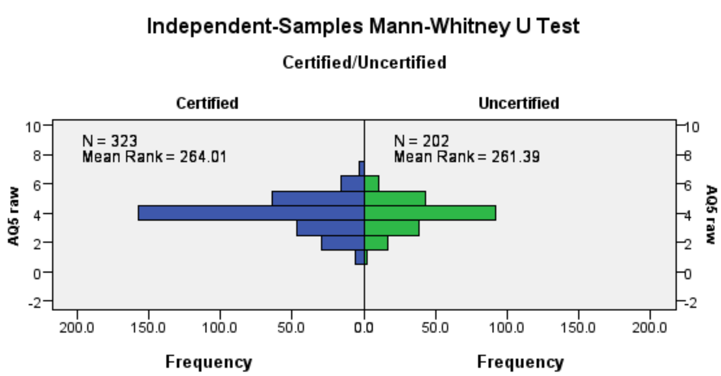
Total N	523
Mann-Whitney U	31,880.500
Wilcoxon W	52,586.500
Test Statistic	31,880.500
Standard Error	1,507.405
Standardized Test Statistic	-.398
Asymptotic Sig. (2-sided test)	.691

Figure 4.21: Results for “Air Quality” Question 3 with Respect to Certification Status



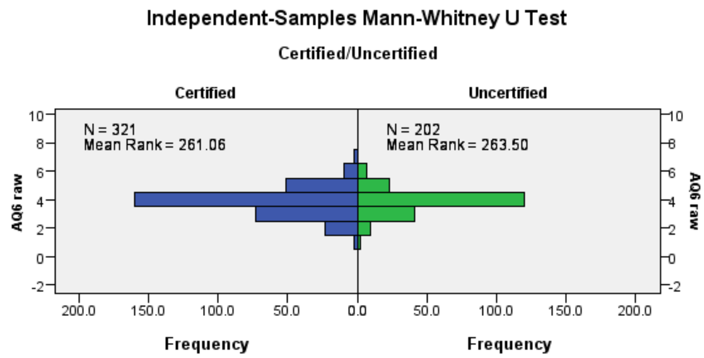
Total N	524
Mann-Whitney U	32,540.500
Wilcoxon W	53,043.500
Test Statistic	32,540.500
Standard Error	1,508.418
Standardized Test Statistic	.012
Asymptotic Sig. (2-sided test)	.990

Figure 4.22: Results for "Air Quality" Question 4 with Respect to Certification Status



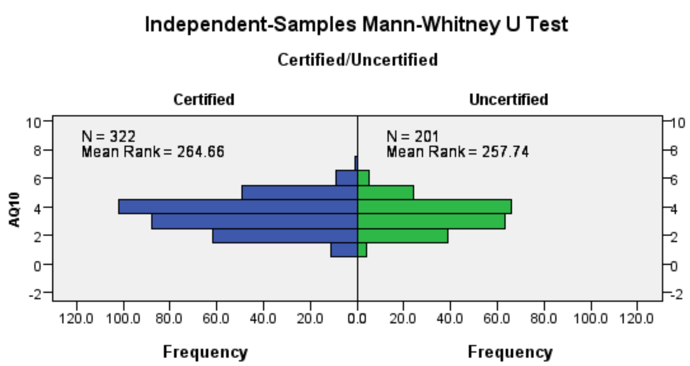
Total N	525
Mann-Whitney U	32,298.000
Wilcoxon W	52,801.000
Test Statistic	32,298.000
Standard Error	1,586.214
Standardized Test Statistic	-.205
Asymptotic Sig. (2-sided test)	.838

Figure 4.23: Results for "Air Quality" Question 5 with Respect to Certification Status



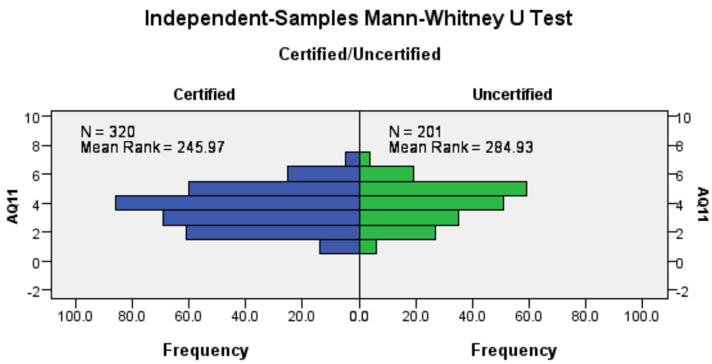
Total N	523
Mann-Whitney U	32,723.500
Wilcoxon W	53,226.500
Test Statistic	32,723.500
Standard Error	1,535.860
Standardized Test Statistic	.197
Asymptotic Sig. (2-sided test)	.844

Figure 4.24: Results for "Air Quality" Question 6 with Respect to Certification Status



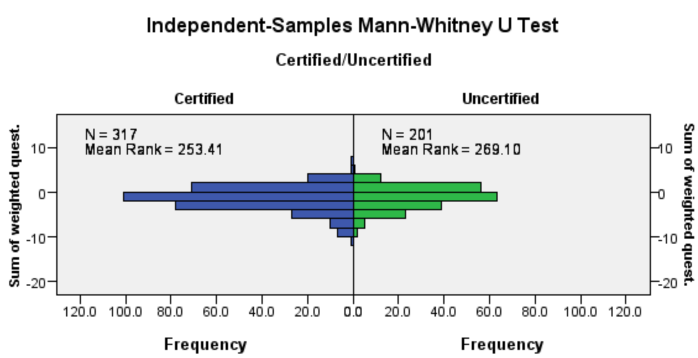
Total N	523
Mann-Whitney U	31,505.500
Wilcoxon W	51,806.500
Test Statistic	31,505.500
Standard Error	1,623.684
Standardized Test Statistic	-.527
Asymptotic Sig. (2-sided test)	.598

Figure 4.25: Result for "Air Quality" Question 10 with Respect to Certification Status



Total N	521
Mann-Whitney U	36,970.500
Wilcoxon W	57,271.500
Test Statistic	36,970.500
Standard Error	1,635.886
Standardized Test Statistic	2.941
Asymptotic Sig. (2-sided test)	.003

Figure 4.26: Results for "Air Quality" Question 11 with Respect to Certification Status



Total N	518
Mann-Whitney U	33,788.500
Wilcoxon W	54,089.500
Test Statistic	33,788.500
Standard Error	1,645.997
Standardized Test Statistic	1.173
Asymptotic Sig. (2-sided test)	.241

Figure 4.27: Results for the Sum of the Weighted Scores with Respect to Certification Status

The median scores of “Air quality” question 1, U=34879, z=1.325, p=0.185; question 2, U=35606.5, z=1.758, p=0.079; question 3, U=31880.5, z=-0.398, p=0.691; question 4, U=32540.5, z=0.012, p=0.990; question 5, U=32298, z=-0.205, p=0.838; question 6, U=32723.5, z=0.197, p=0.844; question 10, U=21505.5, z=-0.527, p=0.598; and the weighted-score sum, U=33788.5, z=1.173, p=0.241, were not statistically different between certified and uncertified malls since the p values were all greater than 0.05. This meant that the temperature, air quality, air flow, and humidity between certified and uncertified malls were perceived to be the same. The score for “Air Quality” question 11 for certified (mean rank=245.97) was significantly lower than uncertified (mean rank=284.93), U=36970.5, z=2.941, p=0.003. This meant that people perceived the outdoor air quality around certified malls to be better than the outdoor air quality around uncertified malls. Since there was a statistical difference between surveying inside and outside of malls for question 11, it was important to verify that the percentages of questionnaire surveyed inside and outside at certified and uncertified malls were similar to ensure that the result was not skewed. Figures 4.28 and 4.29 show the percentage of questionnaires surveyed inside and outside at certified and uncertified malls. The percentage of questionnaires surveyed inside certified malls (22.29%) seemed similar to the percentage of questionnaires surveyed inside uncertified malls (17.73%).

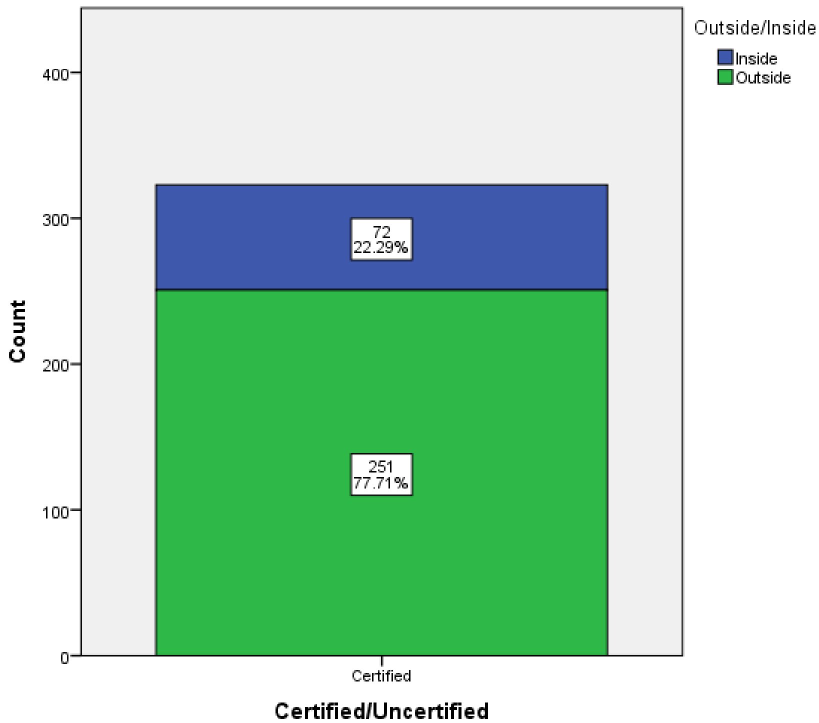


Figure 4.28: Graph of Number of Questionnaires at Certified Malls with Respect to Survey Location

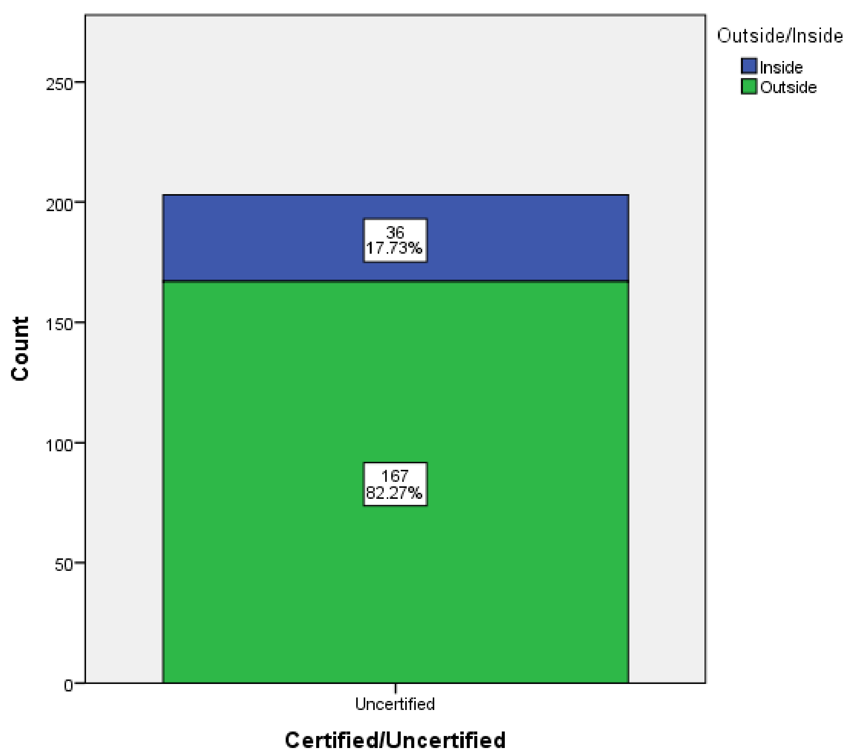


Figure 4.29: Graph of Number of Questionnaires at Uncertified Malls with Respect to Survey Location

"Air Quality" questions 8 and 9 were analyzed with cross tabulations and chi-square test for association. Since the cross tabulation results for questions 8 and 9 did not violate the assumptions of the chi-square test for association as shown in Tables 4.9 and 4.11, respectively, the chi-square test was used to analyze the questions. Shown in Tables 4.10 and 4.12, the chi-square test revealed that there were no statistically significant associations between certified and uncertified malls for question 8, Pearson chi-square (χ^2) (2)=1.566, p=0.457, and for question 9, χ^2(2)=3.121, p=0.210. The chi square-test gives a Pearson chi-square (χ^2) value, and the χ^2 value is converted to a p-value (McLaughlin, 1996). The p-values were greater than 0.05, and therefore the results for questions 8 and 9 meant that the responses to the questions were independent of the certification status of the malls.

Table 4.9: Cross Tabulation of "Air Quality" Question 8 and Certification Status

		AQ8			
		Better	Similar	Worse	Total
Certified	Count	31	43	11	85
	Expected Count	28.9	43.7	12.5	85.0
	% within Status	36.5%	50.6%	12.9%	100.0%
	% within AQ8	83.8%	76.8%	68.8%	78.0%
	% of Total	28.4%	39.4%	10.1%	78.0%
Uncertified	Count	6	13	5	24
	Expected Count	8.1	12.3	3.5	24.0
	% within Status	25.0%	54.2%	20.8%	100.0%
	% within AQ8	16.2%	23.2%	31.3%	22.0%
	% of Total	5.5%	11.9%	4.6%	22.0%
Total	Count	37	56	16	109
	Expected Count	37.0	56.0	16.0	109.0
	% within Status	33.9%	51.4%	14.7%	100.0%
	% within AQ8	100.0%	100.0%	100.0%	100.0%
	% of Total	33.9%	51.4%	14.7%	100.0%

Table 4.10: Chi-Square Test of “Air Quality” Question 8 with Respect to Certification Status

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.566	2	.457
Likelihood Ratio	1.555	2	.460
Linear-by-Linear Association	1.548	1	.213
N of Valid Cases	109		

Table 4.11: Cross Tabulation of “Air Quality” Question 9 and Certification Status

			AQ9			Total
			Yes	No	Don't Know	
Certified/Uncertified	Certified	Count	235	52	34	321
		Expected Count	236.6	46.2	38.2	321.0
		% within Certified/Uncertified	73.2%	16.2%	10.6%	100.0%
		% within AQ9	61.2%	69.3%	54.8%	61.6%
		% of Total	45.1%	10.0%	6.5%	61.6%
	Uncertified	Count	149	23	28	200
		Expected Count	147.4	28.8	23.8	200.0
		% within Certified/Uncertified	74.5%	11.5%	14.0%	100.0%
		% within AQ9	38.8%	30.7%	45.2%	38.4%
		% of Total	28.6%	4.4%	5.4%	38.4%
Total		Count	384	75	62	521
		Expected Count	384.0	75.0	62.0	521.0
		% within Certified/Uncertified	73.7%	14.4%	11.9%	100.0%
		% within AQ9	100.0%	100.0%	100.0%	100.0%
		% of Total	73.7%	14.4%	11.9%	100.0%

Table 4.12: Chi-Square Test of “Air Quality” Question 9 with Respect to Certification Status

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.121	2	.210
Likelihood Ratio	3.157	2	.206
Linear-by-Linear Association	.116	1	.733
N of Valid Cases	521		

The statistical tests for “Air quality” questions 1-6 and 8-10 and the weighted-score sum showed that there were no significant differences in peoples’ perception of IAQ of certified and uncertified malls. The statistical test for “Air Quality” question 11 determined that people thought the outdoor air quality was better around certified malls than around uncertified malls.

4.1.4. Comparing Certification Class – Good, Excellent, and Uncertified

Although there was no difference in the perception of mall IAQ with respect to certification status, there could be differences between the certification classes – ‘Good,’ ‘Excellent,’ and uncertified. This could have happen because many more questionnaires were taken at good malls as compared to excellent malls and the test results could have been influenced more by the data of the good malls. Looking between the certification classes allowed the data for excellent malls not to be overshadowed by the data for good malls. The data were analyzed to explore whether or not people could perceive differences in mall IAQ in regards to certification class. The first dependent variable to be tested was the weighted-score sum. Since the data had outliers as seen in Figure 4.18, analysis of variance (ANOVA) could not be used to analyze the sum (Laerd Statistics, 2013f). Instead, the sum was analyzed with the Kruskal-Wallis test to determine whether there were statistical differences among the certification classes with respect to the weighted-score sum. Table 4.13 summarizes the results of the test and Table 4.14 shows the medians of the sum with respect to the certification class. To ensure that the Kruskal-

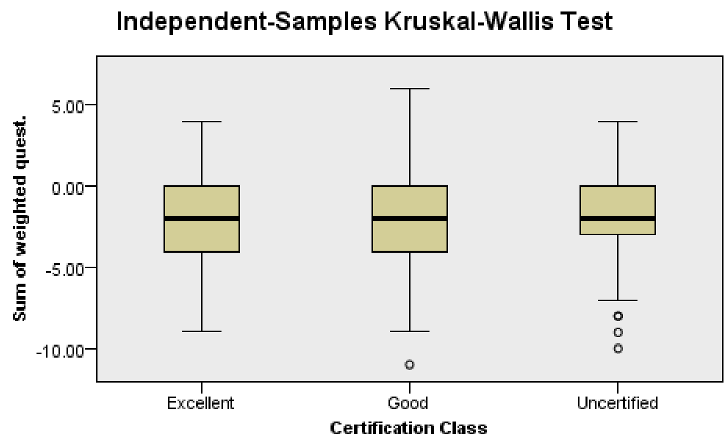
Wallis test was valid for analyzing the median of the data, the shapes of the distributions of the data of the sum with respect to the certification class were examined to see if they were similar (Laerd Statistics, 2013d). Based on visual inspection of Figure 4.30, the shapes of the distributions were the same; therefore, the Kruskal-Wallis test was valid and was used for analysis. The Kruskal-Wallis test showed that there was no significant difference among the excellent (*Mdn*=-2.00), good (*Mdn*=-2.00), and uncertified (*Mdn*=-2.00) certification classes, $\chi^2(2)=1.754$, p=0.416.

Table 4.13: Kruskal-Wallis Test Result for the Sum of the Weighted Scores with Respect to Certification Class

Hypothesis Test Summary				
	Null Hypothesis	**Test**	**Sig.**	**Decision**
1	The distribution of Sum of weighted quest. is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.416	Retain the null hypothesis.
Asymptotic significances are displayed. The significance level is .05.				

Table 4.14: Median of Sum of Weighted Scores with Respect to Certification Class

Certification Class	N	Median
Excellent	73	-2.00
Good	244	-2.00
Uncertified	201	-2.00
Total	518	-2.00



Total N	518
Test Statistic	1.754
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.416

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

Figure 4.30: Boxplot of Sum of Weighted Scores with Respect to Certification Class

"Air Quality" questions 1-6, 10, and 11 were also analyzed using the Kruskal-Wallis test. The summary of the tests for these questions are located in Table 4.15, and the medians of the data for these questions with respect to certification class are located in Table 4.16. Figures 4.31 to 4.37 and 4.39 show the boxplots of the questions with respect to the certification class. By visual inspection of the boxplots, the shapes of the distributions for each question were similar, except for question 11. According to the Kruskal-Wallis test results, there were no statistical differences with respect to the certification classes in the medians of "Air Quality" question 1, $\chi^2(2)=2.785$, $p=0.248$; question 2, $\chi^2(2)=3.931$, $p=0.140$; question 3, $\chi^2(2)=0.173$, $p=0.917$; question 4, $\chi^2(2)=0.588$, $p=0.745$; question 5, $\chi^2(2)=0.527$, $p=0.768$; and question 6, $\chi^2(2)=0.162$, $p=0.922$. Question 10 was statistically different between the certification classes, $\chi^2(2)=7.737$, p=0.021. A pairwise comparisons post-hoc test, shown in Figure 4.38, was conducted, and it revealed that there were statistical differences between 'Excellent' (*Mdn*=4.00) and 'Good' (*Mdn*=3.00) classes (p=0.019) and between 'Excellent' and uncertified (*Mdn*= 3.00) classes (p=0.051≈0.05) but not between 'Good' and uncertified classes. This meant that people perceived the IAQ of 'Excellent' malls to be worse than that of 'Good' and uncertified malls and that they perceived the IAQ of uncertified and 'Good' malls to be the same. Question 11 was also statistically different between the certification classes, $\chi^2(2)=9.273$, p=0.010. The post-hoc analysis, seen in Figure 4.39, showed that there was a statistical difference between 'Good' (*Mdn*=4.00) and uncertified (*Mdn*=4.00) classes (p=0.007) but not between 'Good' and 'Excellent' (*Mdn*=4.00) classes or between 'Excellent' and uncertified classes. This meant that the distribution of question 11 was not statistically the same between 'Good' and uncertified classes. From visual inspection of Figure 4.38, there was more distribution toward the lower score (better outdoor air quality rating) for 'Good' class than for uncertified class. The result for question 11 could be skewed since there was a statistical difference between surveying inside and outside of the malls. Also surveying inside accounted for 17.73% of questionnaires at uncertified malls, 2.63% at 'Excellent' malls, and 28.34% at 'Good' malls.

Table 4.15: Kruskal-Wallis Test Results for "Air Quality" Questions with Respect to Certification Class

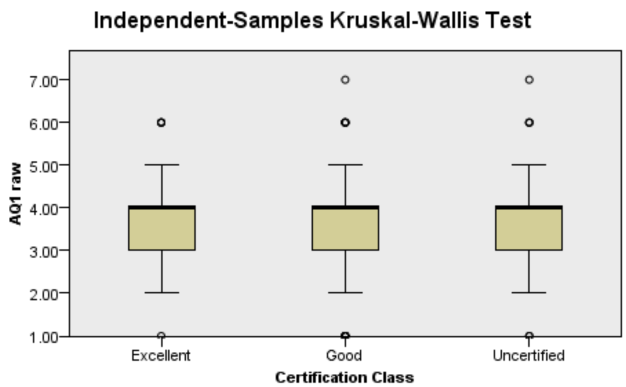
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of AQ1 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.248	Retain the null hypothesis.
2	The distribution of AQ2 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.140	Retain the null hypothesis.
3	The distribution of AQ3 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.917	Retain the null hypothesis.
4	The distribution of AQ4 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.745	Retain the null hypothesis.
5	The distribution of AQ5 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.768	Retain the null hypothesis.
6	The distribution of AQ6 raw is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.922	Retain the null hypothesis.
7	The distribution of AQ10 is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.021	Reject the null hypothesis.
8	The distribution of AQ11 is the same across categories of Certification Class.	Independent-Samples Kruskal-Wallis Test	.010	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 4.16: Mean, Standard Deviation, and Median of "Air Quality" Questions

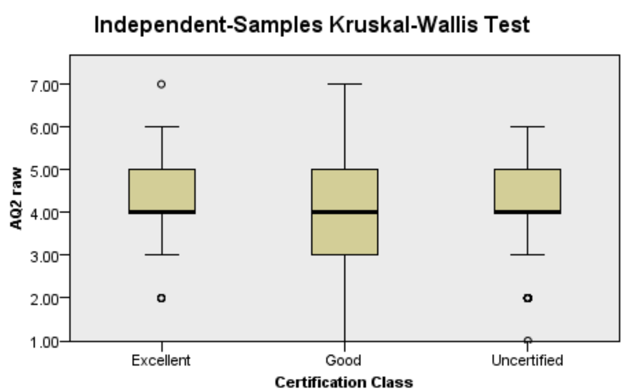
Certification Class		AQ1 raw	AQ2 raw	AQ3 raw	AQ4 raw	AQ5 raw	AQ6 raw	AQ10	AQ11
Excellent	Mean	3.75	4.14	3.88	4.09	3.86	3.89	3.76	3.76
	N	76	76	74	76	76	75	76	76
	Std. Deviation	1.060	1.042	.859	.955	1.140	1.021	1.094	1.118
	Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Good	Mean	3.62	4.01	3.89	4.01	3.96	3.84	3.36	3.63
	N	247	247	246	246	247	246	246	244
	Std. Deviation	1.037	1.063	.895	.855	1.061	.920	1.169	1.453
	Median	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00
Uncertified	Mean	3.77	4.18	3.86	4.02	3.93	3.86	3.41	4.01
	N	203	203	203	202	202	202	201	201
	Std. Deviation	.975	.927	.809	.785	1.012	.841	1.069	1.356
	Median	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00
Total	Mean	3.69	4.09	3.88	4.03	3.93	3.85	3.44	3.80
	N	526	526	523	524	525	523	523	521
	Std. Deviation	1.018	1.011	.856	.843	1.053	.904	1.127	1.380
	Median	4.00	4.00	4.00	4.00	4.00	4.00	3.00	4.00



Total N	526
Test Statistic	2.785
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.248

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

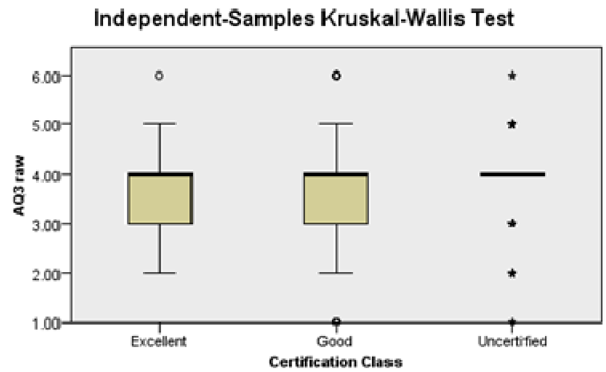
Figure 4.31: Boxplot of “Air Quality” Question 1 with Respect to Certification Class



Total N	526
Test Statistic	3.931
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.140

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

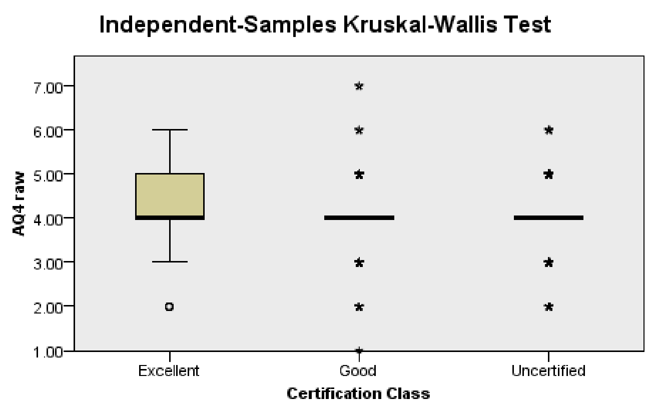
Figure 4.32: Boxplot of “Air Quality” Question 2 with Respect to Certification Class



Total N	523
Test Statistic	.173
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.917

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

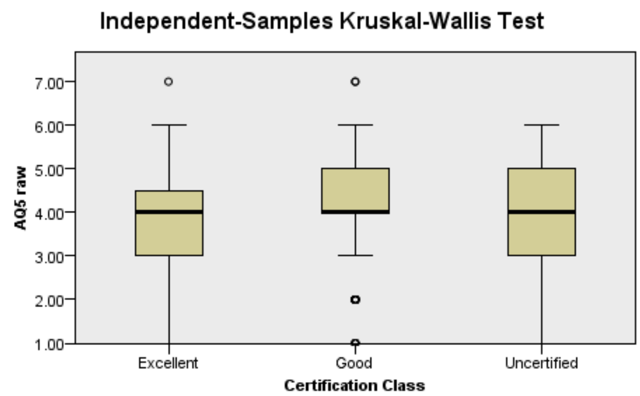
Figure 4.33: Boxplot of “Air Quality” Question 3 with Respect to Certification Class



Total N	524
Test Statistic	.588
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.745

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

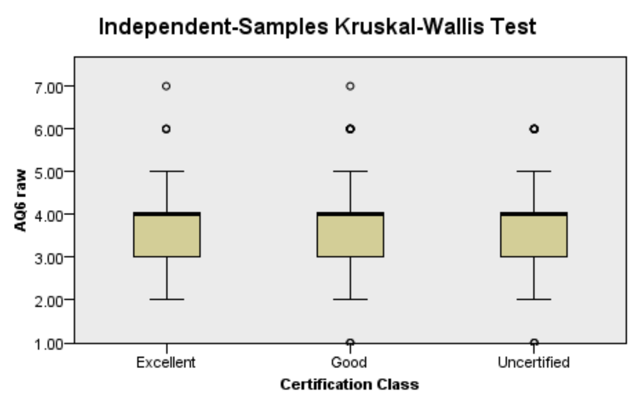
Figure 4.34: Boxplot of “Air Quality” Question 4 with Respect to Certification Class



Total N	525
Test Statistic	.527
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.768

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

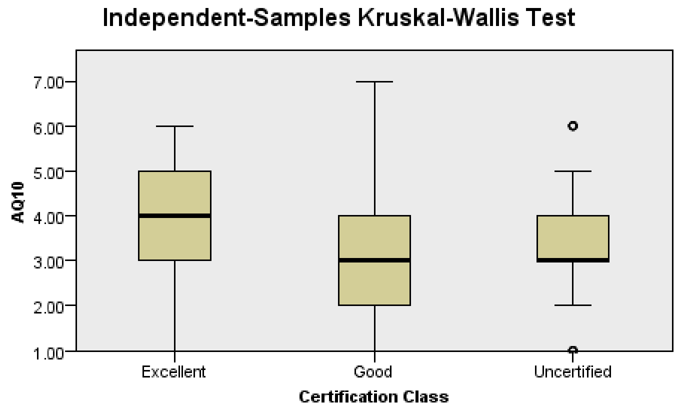
Figure 4.35: Boxplot of “Air Quality” Question 5 with Respect to Certification Class



Total N	523
Test Statistic	.162
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.922

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

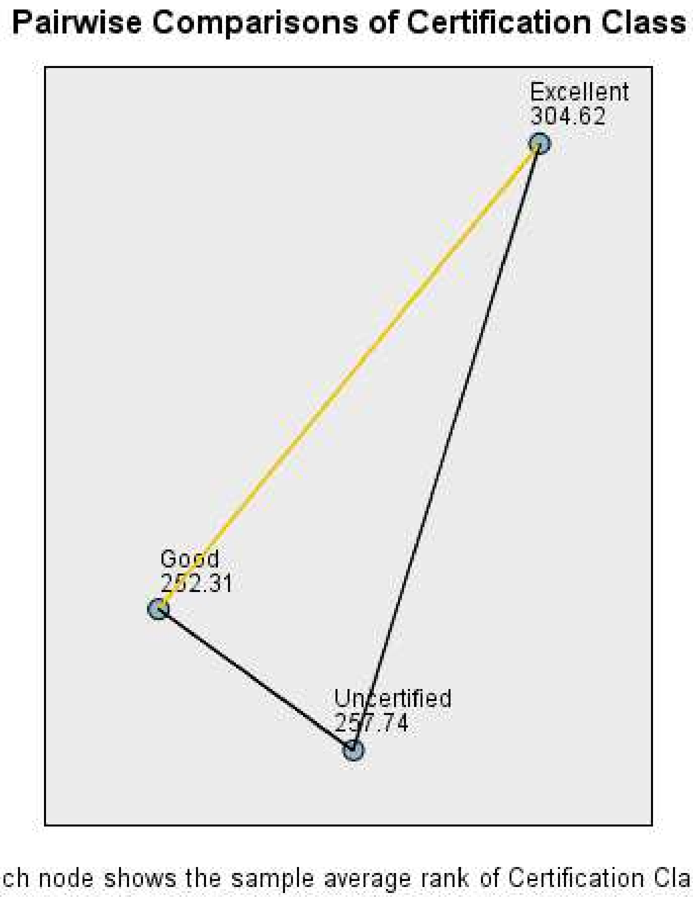
Figure 4.36: Boxplot of “Air Quality” Question 6 with Respect to Certification Class



Total N	523
Test Statistic	7.737
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.021

1. The test statistic is adjusted for ties.

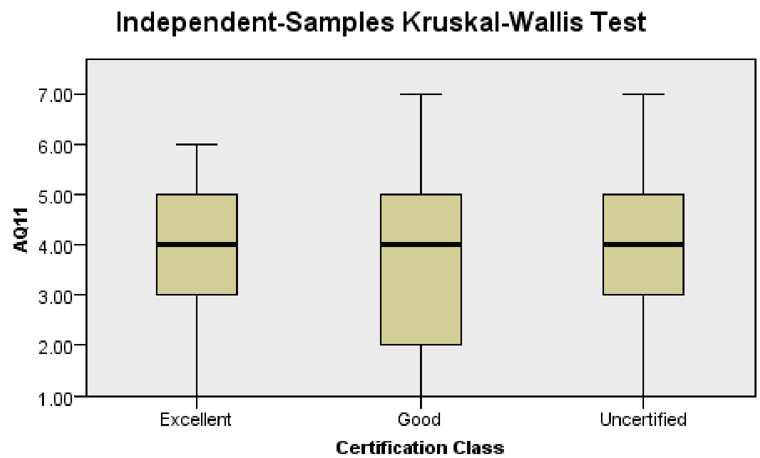
Figure 4.37: Boxplot of “Air Quality” Question 10 with Respect to Certification Class



Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Good-Uncertified	-5.435	13.878	-.392	.695	1.000
Good-Excellent	52.316	19.155	2.731	.006	.019
Uncertified-Excellent	46.881	19.654	2.385	.017	.051

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

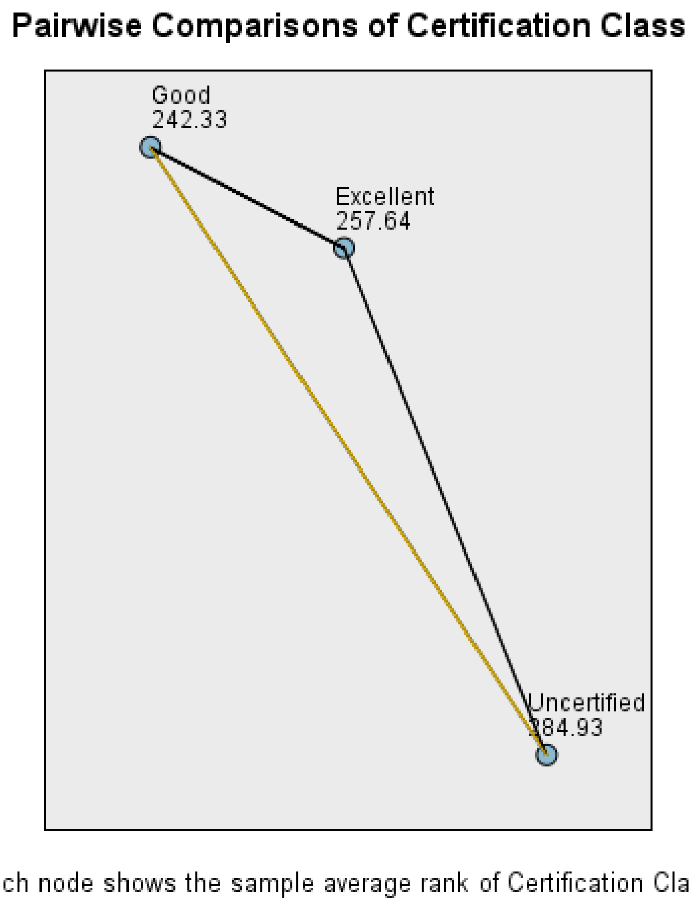
Figure 4.38: Pairwise Comparisons Post-Hoc Test of "Air Quality" Question 10 with Respect to Certification Class



Total N	521
Test Statistic	9.273
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.010

1. The test statistic is adjusted for ties.

Figure 4.39: Boxplot of “Air Quality” Question 11 with Respect to Certification Class



Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Good-Excellent	15.306	19.341	.791	.429	1.000
Good-Uncertified	-42.601	14.024	-3.038	.002	.007
Excellent-Uncertified	-27.295	19.826	-1.377	.169	.506

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 4.40: Pairwise Comparisons Post-Hoc Test of "Air Quality" Question 11 with Respect to Certification Class

“Air Quality” questions 8 and 9 were analyzed by putting their data in cross tabulations and by the chi-square test for association. Tables 4.17 and 4.19 are the cross tabulations, and Tables 4.18 and 4.19 show the chi-square test results.

Table 4.17: Cross Tabulation of “Air Quality” Question 8 and Certification Class

			AQ8			
			Better	Similar	Worse	Total
Certification Class	Excellent	Count	7	6	3	16
		Expected Count	5.4	8.2	2.3	16.0
		% within Certification Class	43.8%	37.5%	18.8%	100.0%
		% within AQ8	18.9%	10.7%	18.8%	14.7%
		% of Total	6.4%	5.5%	2.8%	14.7%
	Good	Count	24	37	8	69
		Expected Count	23.4	35.4	10.1	69.0
		% within Certification Class	34.8%	53.6%	11.6%	100.0%
		% within AQ8	64.9%	66.1%	50.0%	63.3%
		% of Total	22.0%	33.9%	7.3%	63.3%
	Uncertified	Count	6	13	5	24
		Expected Count	8.1	12.3	3.5	24.0
		% within Certification Class	25.0%	54.2%	20.8%	100.0%
		% within AQ8	16.2%	23.2%	31.3%	22.0%
		% of Total	5.5%	11.9%	4.6%	22.0%
Total		Count	37	56	16	109
		Expected Count	37.0	56.0	16.0	109.0
		% within Certification Class	33.9%	51.4%	14.7%	100.0%
		% within AQ8	100.0%	100.0%	100.0%	100.0%
		% of Total	33.9%	51.4%	14.7%	100.0%

Table 4.18: Chi-Square Test of "Air Quality" Question 8 with Respect to Certification Class

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.984	4	.560
Likelihood Ratio	3.013	4	.556
Linear-by-Linear Association	1.154	1	.283
N of Valid Cases	109		

Table 4.19: Cross Tabulation of "Air Quality" Question 9 and Certification Class

			AQ9			Total
			Yes	No	Don't Know	
Certification Class	Excellent	Count	47	13	15	75
		Expected Count	55.3	10.8	8.9	75.0
		% within Certification Class	62.7%	17.3%	20.0%	100.0%
		% within AQ9	12.2%	17.3%	24.2%	14.4%
		% of Total	9.0%	2.5%	2.9%	14.4%
	Good	Count	188	39	19	246
		Expected Count	181.3	35.4	29.3	246.0
		% within Certification Class	76.4%	15.9%	7.7%	100.0%
		% within AQ9	49.0%	52.0%	30.6%	47.2%
		% of Total	36.1%	7.5%	3.6%	47.2%
	Uncertified	Count	149	23	28	200
		Expected Count	147.4	28.8	23.8	200.0
		% within Certification Class	74.5%	11.5%	14.0%	100.0%
		% within AQ9	38.8%	30.7%	45.2%	38.4%
		% of Total	28.6%	4.4%	5.4%	38.4%
Total		Count	384	75	62	521
		Expected Count	384.0	75.0	62.0	521.0
		% within Certification Class	73.7%	14.4%	11.9%	100.0%
		% within AQ9	100.0%	100.0%	100.0%	100.0%
		% of Total	73.7%	14.4%	11.9%	100.0%

Table 4.20: Chi-Square Test of “Air Quality” Question 9 with Respect to Certification Class

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.963	4	.018
Likelihood Ratio	11.842	4	.019
Linear-by-Linear Association	1.185	1	.276
N of Valid Cases	521		

The test showed that there was not a statistically significant association between certification class and question 8, $\chi^2(4)=2.984$, p=0.560. The chi-square test for question 8 might not be reliable because 22% of the expected counts were less than five and the chi-square test assumes no more than 20% of the expected counts to be less than five (Weaver, 2013). The chi-square test revealed that there was a statistically significant association between certification class and question 9, $\chi^2(4)=11.963$, p=0.018. More people thought that the IAQ in ‘Excellent’ malls was unsatisfactory than in ‘Good’ or uncertified malls. Also, when asked if the IAQ was satisfactory, more people were unsure in ‘Excellent’ malls than in ‘Good’ or uncertified malls.

Statistical tests showed that there were no statistical differences in the certification classes for the weighted-score sum and “Air Quality” questions 1-6 and 8. The results for question 8 might be unreliable since it violated a test assumption. There were differences in certification classes for “Air Quality” questions 9, 10, and 11. For question 11, there was more distribution toward the better outdoor air quality rating for good malls than for uncertified malls, and there were no differences between ‘Excellent’ and ‘Good’ malls and between ‘Excellent’ and uncertified malls. However, the results for question 11 could be skewed. For question 9, more people thought that the IAQ was unsatisfactory at ‘Excellent’ malls than at uncertified and ‘Good’ malls. For question 10, the IAQ at ‘Excellent’ malls was rated lower than the IAQ at

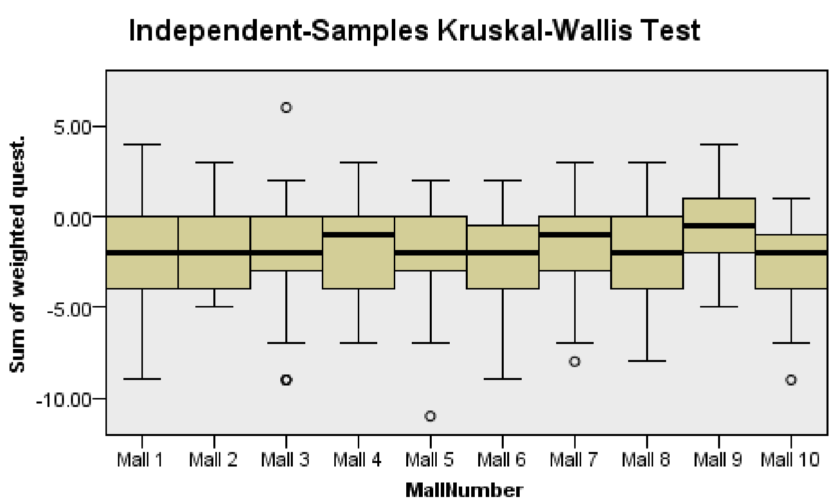
‘Good’ and uncertified malls, and the IAQ at ‘Good’ malls was ranked the same as the IAQ at uncertified malls. It seemed that people thought the IAQ of ‘Excellent’ malls was worse than the IAQ at ‘Good’ and uncertified malls.

4.1.5. Comparisons of Malls – Mall 1 – 10

The malls were ranked to determine which mall had the best IAQ according to people’s perception by analyzing the weighted-score sum. The median and mean of the weighted-score sum with respect to the malls are located in Table 4.21. Since the data of the weighted-score sum had outliers (see Figure 4.41), the ANOVA test could not be performed so the Kruskal-Wallis test was performed instead. The Kruskal-Wallis test showed that there were statistical differences between the malls, $\chi^2(9)=10.912$, $p=0.282$. The post-hoc test, seen in Figure 4.42, revealed that there were differences between Mall 10 (*Mdn*=-2.00) and Mall 9 (*Mdn*=-0.50) ($p<0.001$), between Mall 1 (*Mdn*=-2.00) and Mall 9 ($p=0.049$), and between Mall 3 and Mall 9 ($p=0.025$). The post-hoc test also revealed that there were no statistical differences between the other combinations of malls. Since Mall 9 had the highest median (better overall IAQ-score median) and had statistical differences between malls, it seemed that people perceived Mall 9 to have the best IAQ. The other malls could not be ranked because there were no statistical differences between them. Mall 9 was an uncertified mall yet it was rated higher than ‘Good’ and ‘Excellent’ malls. This implied that, based on people’s perceptions, uncertified malls can have good IAQ even though they have not gone through certification.

Table 4.21: Mean, Number, Standard Deviation, and Median of the Sum of the Weighted Scores with Respect to the Malls

Mall	Mean	N	Std. Deviation	Median
Mall 1	-2.27	49	3.200	-2.00
Mall 2	-2.00	24	2.126	-2.00
Mall 3	-2.07	100	2.471	-2.00
Mall 4	-1.88	48	2.922	-1.00
Mall 5	-1.83	48	2.337	-2.00
Mall 6	-2.25	48	2.547	-2.00
Mall 7	-1.74	50	2.302	-1.00
Mall 8	-2.00	50	2.821	-2.00
Mall 9	-.56	50	2.032	-.50
Mall 10	-2.82	51	2.242	-2.00
Total	-1.95	518	2.570	-2.00

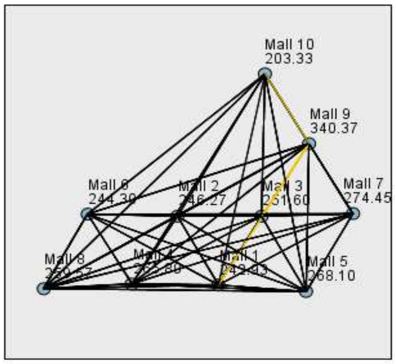


Total N	518
Test Statistic	24.497
Degrees of Freedom	9
Asymptotic Sig. (2-sided test)	.004

1. The test statistic is adjusted for ties.

Figure 4.41: Boxplot of the Sum of the Weighted Scores with Respect to the Malls

Pairwise Comparisons of MallNumber



Each node shows the sample average rank of MallNumber.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Mall 10-Mall 1	39.595	29.688	1.334	.182	1.000
Mall 10-Mall 6	40.969	29.845	1.373	.170	1.000
Mall 10-Mall 2	42.938	36.737	1.169	.242	1.000
Mall 10-Mall 3	48.262	25.537	1.890	.059	1.000
Mall 10-Mall 8	56.237	29.536	1.904	.057	1.000
Mall 10-Mall 4	62.552	29.845	2.096	.036	1.000
Mall 10-Mall 5	64.771	29.845	2.170	.030	1.000
Mall 10-Mall 7	71.117	29.536	2.408	.016	.722
Mall 10-Mall 9	137.037	29.536	4.640	.000	.000
Mall 1-Mall 6	-1.374	30.139	-.046	.964	1.000
Mall 1-Mall 2	-3.342	36.976	-.090	.928	1.000
Mall 1-Mall 3	-8.666	25.880	-.335	.738	1.000
Mall 1-Mall 8	-16.641	29.833	-.558	.577	1.000
Mall 1-Mall 4	-22.957	30.139	-.762	.446	1.000
Mall 1-Mall 5	-25.176	30.139	-.835	.404	1.000
Mall 1-Mall 7	-31.521	29.833	-1.057	.291	1.000
Mall 1-Mall 9	-97.441	29.833	-3.266	.001	.049
Mall 6-Mall 2	1.969	37.103	.053	.958	1.000
Mall 6-Mall 3	7.293	26.060	.280	.780	1.000
Mall 6-Mall 8	-15.268	29.990	-.509	.611	1.000
Mall 6-Mall 5	23.802	30.294	.786	.432	1.000
Mall 6-Mall 7	-30.148	29.990	-1.005	.315	1.000
Mall 6-Mall 9	-96.068	29.990	-3.203	.001	.061
Mall 2-Mall 3	-5.324	33.734	-.158	.875	1.000
Mall 2-Mall 8	-13.299	36.855	-.361	.718	1.000
Mall 2-Mall 4	-19.615	37.103	-.529	.597	1.000
Mall 2-Mall 5	-21.833	37.103	-.588	.556	1.000
Mall 2-Mall 7	-28.179	36.855	-.765	.445	1.000
Mall 2-Mall 9	-94.099	36.855	-2.553	.011	.480
Mall 3-Mall 8	-7.975	25.706	-.310	.756	1.000
Mall 3-Mall 4	-14.290	26.060	-.548	.583	1.000
Mall 3-Mall 5	-16.509	26.060	-.634	.526	1.000
Mall 3-Mall 7	-22.855	25.706	-.889	.374	1.000
Mall 3-Mall 9	-88.775	25.706	-3.454	.001	.025
Mall 8-Mall 4	6.315	29.990	.211	.833	1.000
Mall 8-Mall 5	8.534	29.990	.285	.776	1.000
Mall 8-Mall 7	14.880	29.682	.501	.616	1.000
Mall 8-Mall 9	-80.800	29.682	-2.722	.006	.292
Mall 4-Mall 5	-2.219	30.294	-.073	.942	1.000
Mall 4-Mall 7	-8.565	29.990	-.286	.775	1.000
Mall 4-Mall 9	-74.485	29.990	-2.484	.013	.585
Mall 5-Mall 7	-6.346	29.990	-.212	.832	1.000
Mall 5-Mall 9	-72.266	29.990	-2.410	.016	.718
Mall 7-Mall 9	-65.920	29.682	-2.221	.026	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 4.42: Pairwise Comparisons Post-Hoc Test for the Sum of the Weighted Scores with Respect to the Malls

4.1.6. Analysis of "Air Quality" Questions 7, 7a, 12, 12a, and 13

Based on the 510 responses for question 7, a little bit more than a quarter of respondents (28.2%) have heard of the IAQ Certification Scheme. From discussing with a specialist in IAQ and environmental education, the expected percentage of people who have heard of the IAQ Certification Scheme was around 10% (V. Chan, Personal Communication, February 2014). Of the 144 respondents who said that they have heard of the scheme, 140 of them responded to question 7a (what is the certification class of this mall?). About one-third of the 140 respondents (33.6%) got the certification class of the mall they were in correct, 42.8% got the certification class incorrect, and 23.6% did not know the certification class. The results for question 7 and 7a demonstrated that people, especially the younger people, have learned about the IAQ Certification Scheme.

Based on the 516 responses for question 12, about two-fifths of respondents (40.5%) said that the IAQ of shopping malls affected the amount of money they spent. One hundred nineteen (119) of the 209 respondents that answered yes to question 12 answered question 12a which asked the amount of increase in spending should the IAQ of the mall improve. For question 12a, the average percentage of more money they would spend was +15.5%, the median was +20%, and the mode was +20%. This illustrated that IAQ was pertinent to malls and improvement of IAQ in malls would generate more sales.

For question 13 which asked about interest in courses on IAQ, out of the 526 responses, 12.9% were interested in management, 23.6% in improvement, 4.8% in principle, 9.9% in standards, 16.0% in malls, and 8.4% in offices. About two-fifths (40.9%) were not interested in any IAQ courses. Courses on IAQ in hotels and homes were suggested. The results revealed that a majority of people had some interest in learning about IAQ.

4.2. Comparing Hong Kong's IAQ Objectives & International IAQ Guidelines

Objective 2 consisted of reviewing current Hong Kong IAQ Objectives and performing comparisons with five countries' IAQ guidelines. The guideline values of Hong Kong's IAQ Objectives are all given as eight hour time averages. Guidelines have units of parts per million (ppm) or parts per billion (ppb) of the parameter measured, microgram per cubic meter (μg/m^3), or becquerel per cubic meter (Bq/m^3). If Hong Kong provided guideline values for the same parameter in two different units, both guidelines were included in the tables. Even though the units are different, the guideline values were assumed to represent the same concentration and are equivalently converted by the EPD. For the comparison, of the two classes ('Excellent' and 'Good') the guideline values of the parameters for 'Good' class were used. 'Good' class guidelines values were used because the values represent the maximum allowable values for each of the parameters before the parameter is considered unsatisfactory. As with Hong Kong, if any parameter guidelines from WHO, Canada, Singapore, Malaysia, Australia, or China were given in two different units, both guidelines were included in the tables. The guidelines were again assumed to be equivalently converted and represent the same concentration. International guidelines are all given as eight hour time averages unless specified differently in the tables.

Carbon monoxide concentrations can be measured in units of ppm or μg/m^3. Hong Kong's carbon monoxide guideline value for 'Good' class is 8.7 ppm or equivalently 10,000 μg/m^3. Canada's guideline values for carbon monoxide are 25 ppm and 10 ppm for one hour and 24 hours respectively. Alternatively, Canada's carbon monoxide guideline values in units of μg/m^3 are 28,600 and 11,500 for one hour and 24 hours respectively. Despite having guidelines in the same units, it is difficult to compare Hong Kong's carbon monoxide guideline to Canada's because the relationship between the concentration of carbon monoxide over time is unknown. It can be observed that Hong Kong's eight hour time average guideline is between Canada's guidelines for one hour and 24 hours. WHO, Singapore and Australia share the same guideline value of 9 ppm or equivalently 10,000 $\mu g/m^3$ for carbon monoxide. Similarly, Malaysia, China, and Canada share the same guideline value of 10 ppm or equivalently 11,500 $\mu g/m^3$ except for a minor difference from Canada. The carbon monoxide guideline from Canada was specified as a 24 hour average rather than an eight hour average like Malaysia and China. Comparisons indicate that Hong Kong's guideline is on par with three of the countries and better than the guidelines of two countries. Table 4.22 below shows the carbon monoxide guidelines for each country and WHO. Values with an asterisk (*) were converted and are equivalent to guidelines established by the country or organization.

Table 4.22: Carbon Monoxide (CO) Guidelines

Country / Organization	CO Guideline		Time Average (if not eight hrs)
Hong Kong[48]	8.7 ppm	10,000 $\mu g/m^3$	
WHO[127]	*8.7 – 9 ppm	10,000 $\mu g/m^3$	
Canada[18, 19]	25 ppm	28,600 $\mu g/m^3$	1 hr
	10 ppm	11,500 $\mu g/m^3$	24 hrs
Singapore[62]	9 ppm	10,000 $\mu g/m^3$	
Malaysia[89]	10 ppm	*11,500 $\mu g/m^3$	
Australia[14]	9 ppm	10,000 $\mu g/m^3$	
China[14]	10 ppm	*11,500 $\mu g/m^3$	

Respirable suspended particulate (RSP) guideline values were all provided in units of $\mu g/m^3$. RSP guideline values for Hong Kong, Singapore, Malaysia, and Australia are 180, 50, 150, and 90 $\mu g/m^3$ respectively. Singapore's guideline was changed from 150 $\mu g/m^3$ to 50 $\mu g/m^3$

in 2009, a relatively low concentration in comparison with Hong Kong, because the government of Singapore believed that this could be achieved with better air filtration systems (National Environment Agency, 2010). No RSP guideline values were recommended by WHO, Canada, and China (see Table 4.23). Hong Kong's RSP guideline value is the highest followed by Malaysia, Australia, and Singapore.

Table 4.23: Respirable Suspended Particulates (RSP) Guidelines

Country / Organization	RSP Guideline
Hong Kong[48]	180 $\mu g/m^3$
WHO[127]	N/A
Canada[18, 19]	N/A
Singapore[62]	50 $\mu g/m^3$
Malaysia[89]	150 $\mu g/m^3$
Australia[14]	90 $\mu g/m^3$
China[14]	N/A

Ozone concentrations can be measured in units of ppb, ppm, or $\mu g/m^3$ depending on the country. The Hong Kong guideline value for ozone 'Good' class is 61 ppb or 150 $\mu g/m^3$. Canada's recommended ozone concentration is 20 ppb or 50 $\mu g/m^3$, three times lower than Hong Kong's guideline. Malaysia and Singapore have established 120 $\mu g/m^3$ as the guideline value for ozone which can be considered on par with Hong Kong with a difference of 30 $\mu g/m^3$. Australia's ozone guideline value is 240 $\mu g/m^3$ while China's is 384 $\mu g/m^3$, both of which are higher than Hong Kong's ozone guideline. Hong Kong's ozone guideline value is the third highest among guidelines compared after China (384 $\mu g/m^3$) and Australia (240 $\mu g/m^3$). Hong Kong's guideline values along with international guidelines converted to their equivalent values in units of ppb, ppm, and $\mu g/m^3$ are presented in Table 4.24 marked with an asterisk (*).

Table 4.24: Ozone (O_3) Guidelines

Country / Organization	O_3 Guideline		
Hong Kong[48]	61 ppb	*0.061 ppm	150 µg/m³
WHO[127]	60 ppb	0.06 ppm	150 µg/m³
Canada[18, 19]	20 ppb	*0.020 ppm	50 µg/m³
Singapore[62]	*49 ppb	0.05 ppm	120 µg/m³
Malaysia[89]	*49 ppb	0.05 ppm	*120 µg/m³
Australia[14]	*98 ppb	*0.1 ppm	240 µg/m³
China[14]	*156 ppb	0.16 ppm	*384 µg/m³

The guideline value for formaldehyde 'Good' class in Hong Kong is 81 ppb equivalent to 100 µg/m^3. WHO also recommends a guideline value of 100 µg/m^3 while Canada recommends a guideline value half of Hong Kong and WHO's guideline. Singapore and Australia established a guideline value of 120 µg/m^3 for formaldehyde which when converted to units of ppm, is equivalent to Malaysia and China's recommended guideline value of 0.1 ppm. Comparisons indicate that Hong Kong's formaldehyde guideline is on par with WHO, worse than Canada, and better than Singapore, Malaysia, Australia, and China formaldehyde guidelines. Table 4.25 below shows the recommended formaldehyde guidelines for each country and WHO. Guidelines that were converted to units other than that provided by the country are marked with an asterisk (*).

Table 4.25: Formaldehyde (HCHO) Guidelines

Country / Organization	Formaldehyde Guideline		
Hong Kong[48]	81 ppb	*0.081 ppm	100 µg/m^3
WHO[127]	*81 ppb	*0.081 ppm	100 µg/m^3
Canada[18, 19]	40 ppb	*0.040 ppm	50 µg/m^3
Singapore[62]	*96 ppb	0.1 ppm	120 µg/m^3
Malaysia[89]	*96 ppb	0.1 ppm	*120 µg/m^3
Australia[14]	*96 ppb	*0.1 ppm	120 µg/m^3
China[14]	* 96 ppb	0.1 ppm	*120 µg/m^3

Radon's guideline value for 'Good' class in Hong Kong is set at 200 Bq/m^3. Canada established a recommended guideline value of 200 Bq/m^3 as well making it on par with Hong Kong's. Australia's radon guideline of 200 Bq/m^3 is established as the annual average rather than an eight hour average making it difficult to accurately compare and draw conclusions. Hong Kong and Australia's radon guideline of 200 Bq/m^3 is double the WHO recommended radon guideline of 100 Bq/m^3. Singapore, Malaysia, and China currently have no recommended guideline values for radon. Below, Table 4.26 lists the radon guidelines for each country and WHO.

Table 4.26: Radon (Rn) Guidelines

Country / Organization	Rn Guideline
Hong Kong[48]	200 Bq/m^3
WHO[127]	100 Bq/m^3
Canada[18, 19]	200 Bq/m^3
Singapore[62]	N/A
Malaysia[89]	N/A
Australia[14]	200 Bq/m^3 (annual avg.)
China[14]	N/A

Total volatile organic compounds (TVOC) concentrations can be measured in units of ppb, ppm, or µg/m^3. Hong Kong's 'Good' class guideline value for TVOC is set to 261 ppb or 600 µg/m^3. Canada provides two guideline values for TVOC, one for target level and one for action level. Canada's target level, the TVOC concentration that should be aimed for, is 100 µg/m^3. Canada recommends that action be taken at a TVOC concentration greater than 500 µg/m^3. The two Canadian TVOC guidelines taken from the Canadian government department Health Canada were observed to be relatively low in comparison with Hong Kong. Hong Kong's TVOC guideline is above Canada's target and action guidelines. TVOC guidelines for Singapore and Malaysia were taken from Singapore government Standard SS554-*Code of Practice for Indoor Air Quality for Air-Conditioned Buildings* and Malaysian government document *Guidelines on Indoor Environmental Quality (IEQ) for Government Office Buildings* and it was observed that the guidelines were high compared to Hong Kong. A TVOC concentration guideline value of 3,000 ppb is set for Singapore and Malaysia which is over ten times higher than Hong Kong's TVOC guideline, a significant difference. The TVOC guideline value for Australia is 250 µg/m^3. When compared to Australia's TVOC guideline, Hong Kong's guideline is more than double the concentration. WHO and China do not provide TVOC concentrations for guidelines. Table 4.27 shows the recommended TVOC concentration for each country and WHO in the three different units. Guidelines converted to different units are marked with an asterisk (*).

Table 4.27: Total Volatile Organic Compounds (TVOC) Guidelines

Country / Organization	TVOC Guideline		
Hong Kong[48]	261 ppb	*0.261 ppm	600 µg/m^3
WHO[127]	N/A		
Canada[18, 19]	*44 ppb (target level) *218 ppb (action level)	*0.044 ppm (target level) *0.218 ppm (action level)	100 µg/m^3 (target level) 500 µg/m^3 (action level)
Singapore[62]	3,000 ppb	*3 ppm	*6897 µg/m^3
Malaysia[89]	*3,000 ppb	3 ppm	*6897 µg/m^3
Australia[14]	*109 ppb	*0.109 ppm	250 µg/m^3 (target)
China[14]	N/A		

Carbon dioxide concentrations can be measured in ppm or mg/m^3. A concentration of 1,000 ppm for carbon dioxide is used for the Hong Kong 'Good' class guideline which is the same as Malaysia's recommended guideline value. China's recommended carbon dioxide concentration is 1,800 mg/m^3. Since neither Hong Kong nor Malaysia provide their guideline in mg/m^3, the conversion rate between mg/m^3 and ppm is unknown. WHO, Canada, and Australia currently do not have quantitative guideline values for carbon dioxide but recommend keeping carbon dioxide levels as low as possible. Table 4.28 below shows the recommended carbon dioxide concentration for each country and WHO.

Table 4.28: Carbon Dioxide (CO_2) Guidelines

Country / Organization	CO_2 Guideline
Hong Kong[48]	1, 000 ppm
WHO[127]	N/A
Canada[18, 19]	N/A
Singapore[62]	700 ppm above outdoor concentrations
Malaysia[89]	1, 000 ppm
Australia[14]	N/A
China[14]	1, 800 mg/m^3

Units for nitrogen dioxide concentrations can be ppb, ppm, or $\mu g/m^3$. Hong Kong's 'Good' class guideline value for nitrogen dioxide is 80 ppb or equivalently 150 $\mu g/m^3$. WHO recommended concentrations for nitrogen dioxide at one hour and annually are 200 $\mu g/m^3$ and 40 $\mu g/m^3$ respectively. Canada also provides short term and long term nitrogen dioxide guidelines at one hour and 24 hours. At one hour, Canada recommends a nitrogen dioxide concentration of 0.25 ppm equivalent to 480 $\mu g/m^3$. At 24 hours, Canada recommends a nitrogen dioxide concentration of 0.05 ppm equivalent to 100 $\mu g/m^3$. Again, a direct comparison cannot be made between Hong Kong, WHO, and Canada because of the difference in the time averages but it is noted that Hong Kong's guideline for eight hours is between the one hour and 24 hour guideline from WHO and greater than Canada's one hour and 24 hour guidelines. There are currently no recommended nitrogen dioxide guideline values for Singapore, Malaysia, Australia, or China. Each countries' and WHO's nitrogen dioxide guidelines are presented Table 4.29. Asterisked values (*) represent values that were equivalently converted.

Table 4.29: Nitrogen Dioxide (NO_2) Guidelines

Country / Organization	NO_2 Guideline			Time Average (if not eight hrs)
Hong Kong[48]	80 ppb	*0.080 ppm	150 $\mu g/m^3$	
WHO[127]	*107 ppb	*0.107 ppm	200 $\mu g/m^3$	1 hr
	*20 ppb	*0.02 ppm	40 $\mu g/m^3$	Annual
Canada[18, 19]	*250 ppb	0.25 ppm	480 $\mu g/m^3$	1 hr
	*50 ppb	0.05 ppm	100 $\mu g/m^3$	24 hrs
Singapore[62]	N/A			
Malaysia[89]	N/A			
Australia[14]	N/A			
China[14]	N/A			

Hong Kong dictates a maximum level of 1,000 CFU/m^3 for airborne bacteria count in order to be considered satisfactory. In Singapore and Malaysia, the maximum allowable concentration for airborne bacteria is 500 CFU/m^3, half of the concentration dictated by Hong Kong. WHO, Canada, Australia, and China currently do not provide guidelines for airborne bacteria count. Table 4.30 summarizes the airborne bacteria guidelines for each country and WHO.

Table 4.30: Airborne Bacteria Count (ABC) Guidelines

Country / Organization	ABC Guideline
Hong Kong[48]	1,000 CFU/m^3
WHO[127]	N/A
Canada[18, 19]	N/A
Singapore[62]	500 CFU/m^3
Malaysia[89]	500 CFU/m^3
Australia[14]	N/A
China[14]	N/A

Airborne fungi is the new parameter promised to be included in the next revision of the IAQ Objectives by the EPD so currently Hong Kong has no guideline value for airborne fungi. WHO, Canada, Australia, and China also do not have guideline values for airborne fungi. Singapore's guideline value for airborne fungi is 500 CFU/m^3 and Malaysia's is 1,000 CFU/m^3 (see Table 4.31).

Table 4.31: Airborne Fungi Guidelines

Country / Organization	Airborne Fungi Guideline
Hong Kong[48]	N/A
WHO[127]	N/A
Canada[18, 19]	N/A
Singapore[62]	500 CFU/m^3
Malaysia[89]	1, 000 CFU/m^3
Australia[14]	N/A
China[14]	N/A

4.3. Recent IAQ Technology

The third and final objective of this project was to research and provide information on the latest IAQ technology that seemed useful for Hong Kong shopping malls to use. This section includes information on three different technologies: Enhanced Media Filtration (EMF) technology, Photocatalytic Oxidation, and the Honeywell IAQPoint2.

Mechanical Ventilation Air Conditioning (MVAC) systems are used in commercial buildings throughout Hong Kong, including shopping malls. These MVAC systems typically use High Efficiency Particulate Arresting (HEPA) air filters to capture particles from the air. In 2003, the *Guidance Notes for the Management of Indoor Air Quality* (GN) suggested that HEPA filters be used in the MVAC systems that cool Hong Kong buildings (The Government of the HKSAR IAQ Management Group, 2003b). HEPA air filters are able to remove 99.97% of airborne microorganisms as small as 0.3 microns. The standard size of particles air filters are tested with is 0.3 microns because typically, the smallest sized microorganisms in the air are approximately 0.3 microns (IEQ Global, 2013b; HubPages, 2014). Despite HEPA filter's impressive performance, it is useful to investigate if there are more up-to-date air filters or other products that could enhance the performance of MVAC systems. This section discusses three products that came up when investigating IAQ technology: Enhanced Media Filtration (EMF) technology, Photocatalytic Oxidation, and the Honeywell IAQPoint2.

4.3.1. Enhanced Media Filtration (EMF) Technology

EMF technology is more recent than HEPA technology and there is a lack of professional reviews done on the technology. However, from what manufacturing companies that produce and sell products with this technology have said, the technology seems worth learning more about. The following is a synopsis on the information gathered about EMF technology from manufacturers' websites and from sites where people are able to buy products utilizing the technology. EMF technology was developed with the U.S. Department of Defense in response to the threat of germ warfare. EMF technology produces a media filter efficiency of 99.99% at 0.3 microns, while HEPA filters have an efficiency of 99.97% at 0.3 microns. EMF filters also kill microorganisms, getting rid of them for good (IEQ Global, 2013c; HubPages, 2014). The difference between HEPA and EMF filters is in the EMF filter's sealed off filter chamber. HEPA filters use a dense paper medium that can allow airborne contaminants to build up around a poorly sealed filter. A build-up of contaminants occurs if the blower motor of the air handling unit does not have enough power to effectively push unfiltered air through the HEPA filter. These contaminants are then able to enter back into the air we breathe (HubPages, 2014). EMF filters create airflow inside of a sealed filter chamber so that air particles get trapped inside of the chamber, with no chance of escaping back into the breathable air. After the chamber traps the airborne contaminants, EMF Germicidal technology treats the contaminants. During the germicidal treatment of the microorganisms the EMF filter takes advantage of the high energy field created by the air purification system to kill fungi, bacteria, mold, and viruses by breaking through their DNA (IEQ Global, 2013c; HubPages, 2014).

EMF technology has progressed from being a military technology to being used in clean room manufacturing processes where it is important for the air to be completely free from chemicals. Now, EMF technology is available for home, office, and commercial use. The United States Food and Drug Administration classified purification systems that utilize the EMF technology as Class II Medical Devices. That means the technology is advanced enough to remove airborne particles for health and medical purposes. HealthWay is a company that produced the first air purification system with EMF technology (IEQ Global, 2013c).

HealthWay tested its air purifier and real-time particle counters displayed reduction of airborne pollutants in a room when the purifier was in use (IEQ Global, 2013c).

Independent laboratories and organizations have also tested EMF technology, such as Mount Elizabeth Hospital's Intensive Care Unit in Singapore and the National Indoor Environmental Quality Research and Innovation, Inc. in the United States (IEQ Global, 2013b). IEQ Global is the corporation that tested an EMF purification system for Mount Elizabeth Hospital. IEQ Global designs, manufactures, and supplies energy efficient products that adhere to global standards (IEQ Global, 2013a). In response to the test the hospital's Chief Infection Control Officer said:

> The test results of the comprehensive air purification trial and demonstration for our Neonatal Intensive care unit proved that the EMF air purification systems are able to improve the indoor air quality by significantly reducing small airborne particles and TVOC. The systems are able to trap and kill airborne organisms which are most beneficial to our patients and staff working in the ICU setting (IEQ Global, 2013b).

The National Indoor Environmental Quality Research and Innovation, Inc. is a for-profit firm that researches IAQ and products meant to improve IAQ (NIEQRI, 2004). The corporation tested EMF Air Purification Systems to achieve 99.99% efficiency in the elimination of all virus-sized (0.3 microns) airborne contaminants. The firm also proved that EMF technology is capable of breaking down the molecular structures of contaminants, rendering them inert (IEQ Global, 2013b).

EMF filters can be purchased for about £68 online without buying an entire EMF Air Purification System and they only need to be replaced once a year (Allersafe, 2014a; BestBuysGroup, 2013). The EMF filter is 30 centimeters or 12 inches in diameter (Allersafe, 2014b; Healthy Air, 2014).

4.3.2. Photocatalytic Oxidation

Photocatalytic Oxidation is another new IAQ technology. It has been examined in and written about in peer-reviewed journals (Destaillats et al., 2012; Kim & Yu, 2013). Photocatalytic oxidation is a process in which UV light rays are aimed at an air filter coated with titanium oxide or another type of catalyst. When the UV light rays hit the titanium oxide or catalyst, hydroxyl radicals and super-oxide ions form. The super-oxide ions are electrons that are highly reactive. The ions hit other particles in the air, such as bacteria and volatile organic compounds (VOCs) and immediately combine with them. After the ions combine with their targets, chemical reactions take place that oxidize the pollutant. This breaks down the pollutant's chemical structure and results in by-products of carbon dioxide and water molecules, making the air less contaminated (PeakPureAir, 2013).

Photocatalytic oxidation is now the focus of Lawrence Berkeley National Laboratory's Indoor Environment Department in the United States. The department's research aims to reduce both VOCs in the air and energy use. The department is experimenting with using the Photocatalytic technology inside of HVAC systems and plans on doing studies with different catalysts, other than the standard titanium oxide (Environmental Energy Technologies Division, 2014).

Lawrence Berkeley National Laboratory, in conjunction with Arizona State University in the United States, did a research study on the oxidation technology. The goal of the study was to evaluate the performance of a Photocatalytic Oxidation air cleaner prototype under realistic conditions such as, the presence of a VOC mixture similar to what is typically found in indoor environments. The air cleaner prototype was also exposed to flow conditions similar to those experienced inside of buildings, i.e. the air velocities created by heating, ventilating, air-conditioning (HVAC) systems. The study reported the removal efficiencies of the major VOCs that reside inside of buildings. Photocatalytic oxidation was reported to remove different VOCs from the air with as much as 90 - 100% efficiency. This efficiency may be increased after more studies are done using different types of filters. The study also supported the feasibility of using the oxidation technology inside of HVAC systems (Destaillats et al., 2012).

A downside to the photocatalytic oxidation technology is that the chemical reactions may result in harmful byproducts. However, this technology is continuously being studied and improved to address this setback (Destaillats et al., 2012).

4.3.3. Honeywell IAQPoint2

Honeywell IAQPoint2 is a monitoring device capable of communicating with MVAC systems released by Honeywell Analytics in 2012. The manufacturers of the product provide information on the specifications and abilities of the IAQPoint2. Although this product is not peer-reviewed, the information provided by the manufacturers is a source Hong Kong shopping malls may use to determine if looking more into the product is advantageous. IAQPoint2 offers simultaneous triple monitoring capabilities with built-in sensors to detect temperature, relative humidity, and either carbon dioxide (CO_2) or volatile organic compounds (VOCs). The temperature, relative humidity, and CO_2 or VOCs can be set to a specified level. When the IAQPoint2 detects a level greater than the specified level, the IAQPoint2 can send signals to the MVAC system to turn on or increase ventilation. On the other hand, if levels are lower than the specified level or the building is closed, IAQPoint2 can send signals to turn off the MVAC system. This allows for energy efficient MVAC systems that only need to be turned on when there is a demand for it. IAQPoint2 can be set to increase ventilation during peak hours of the day as well. IAQPoint2 communicates with MVAC systems through either Building Automation

Control network (BACnet) or Modbus (Honeywell, 2012). BACnet is also referred to as ANSI/ASHRAE standard 135-2008 or ISO 16484-5 and was developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in 1995 (ASHRAE, n.d.). BACnet is a "data communication protocol developed…to standardize communications between building automation devices from different manufacturers, allowing data to be shared and equipment to work together easily" (BACnet International, 2013). Modbus was developed by Modicon in 1979 as a messaging structure "to communicate between intelligent devices and sensors and instruments" (Modbus Organization, 2014).

IAQPoint2 is flexible and can be installed on the wall or in the air ducts of ventilation systems. IAQPoint2 not only meets the ASHRAE 62.1 Standards on demand-controlled ventilation and energy efficiency but also OSHA and state of California regulations on air quality/safety and volatile organic compounds monitoring. ASHRAE 62.1 Standards are internationally recognized and accepted standards for designing ventilation systems and achieving satisfactory IAQ (ASHRAE, n.d.). IAQPoint2 can be ordered online and costs approximately $215 USD.

5. Conclusions and Recommendations

Conclusions drawn from questionnaire results appear to demonstrate that the IAQ Certification Scheme is ineffective for shopping malls and that the Scheme makes no noticeable difference in IAQ from a mall patron's point of view. However, this may not be true since all of the conclusions of this study are based on public opinion and not from scientific observations. Due to the fact that the gases and bacteria monitored through the Scheme were not physically measured for this study, it is unknown if the Scheme is helping to lower levels of harmful gases and bacteria in malls that people cannot detect such as radon, nitrogen dioxide, and carbon monoxide. Nevertheless, the IAQ of 'Excellent' malls were subjectively rated the worst even though they were supposed to have better IAQ than 'Good' malls objectively. This might show that the 'Excellent' malls do not maintain the upkeep of IAQ after being certified, and it is recommended that the indoor air of the 'Excellent' malls be physically measured to verify this claim. If this claim is true, then the IAQ Certification Scheme should implement more stringent and frequent post-certification measures to ensure that the certified malls maintain satisfactory IAQ. After showing the survey results to a representative of this project's sponsor, Business Environment Council Limited, it was concluded that people's awareness for the IAQ Certification Scheme was higher than expected. Also, it was found that many people are interested in learning more about IAQ. The EPD should strive to raise more awareness of the Certification Scheme and take initiatives to make the IAQ Information Centre more publicized and accessible. This way, people who want to learn more about IAQ can be informed about the resources available for them to do so.

Another recommendation results from a large percentage of people surveyed who said that they would spend more money in malls if the IAQ in the mall were improved. This should be motivation for shopping malls to improve their IAQ and become certified through the IAQ Certification Scheme. Not only could improving the mall's IAQ increase the amount of money many of the mall's customers spend, being certified could allow the mall to advertise that they have satisfactory IAQ, and possibly attract more customers. Uncertified malls that have not gone through the certification process before should attempt to become certified, since the public perceives the IAQ of uncertified malls to be as good as that of 'Good' class and better than that of 'Excellent' class malls. The public's opinions of the IAQ in uncertified malls may indicate that uncertified malls meet the requirements to become certified through the IAQ Certification

Scheme though this cannot be proven without physically measuring the IAQ parameters. If uncertified malls were to become certified, they could potentially increase their revenue by advertising their certification and attracting more customers. In addition, becoming certified could increase the malls' profits by awarding them with BEAM credits.

From the comparisons of the Hong Kong IAQ Objectives with WHO, Canada, Singapore, Malaysia, Australia and China, it is recommended that the EPD update the Hong Kong IAQ Objectives. For the most part, Hong Kong's IAQ Objectives are on par or better than the guidelines compared but there are a few parameters that should be improved. Namely the parameters that justify an update of the IAQ Objectives are respirable suspended particulates (RSP), total volatile organic compounds (TVOC), and airborne fungi.

Comparisons showed that Hong Kong's guideline value of 180 $\mu g/m^3$ for 'Good' class RSP parameter is higher than RSP guidelines in Singapore, Malaysia, and Australia. Hong Kong's RSP guideline value is twice the guideline suggested by Australia and over three times the Singapore guideline. Keeping the RSP guideline value at 180 $\mu g/m^3$ could lead to negative consequences such as reduced lung function and other health effects as described in the Background section. It would be wise for the EPD to conduct investigations and consider lowering the maximum allowable concentration of RSP permitted in order to be considered satisfactory.

Another parameter that should be considered updating by the EPD is TVOC. TVOC causes respiratory tract irritation and increases the chances of cancer so exposure to high concentrations is not recommended. Hong Kong's TVOC guideline value for 'Good' class is 600 $\mu g/m^3$. The Canadian government considers a concentration over 500 $\mu g/m^3$ for TVOC to be concerning and recommends that action be taken to lower the TVOC concentration.

Buildings in Hong Kong are certified as satisfactory and awarded ‘Good’ class if the building complies with the Hong Kong TVOC guideline value of 600 μg/m^3. This means that by Canadian standards, all certified ‘Good’ class buildings that are supposed to have satisfactory IAQ need to investigate and eliminate sources of TVOC. Canada’s target concentration for TVOC is 100 μg/m^3 which is six times the current TVOC guideline value in Hong Kong. Hong Kong’s TVOC guideline value is also over two times the Australian recommended guideline of 250 μg/m^3. It is recommended that the EPD determine a safe and appropriate TVOC concentration for Hong Kong in order to properly protect its people from increased risk of cancer.

Lastly, it is recommended that the EPD update Hong Kong’s IAQ Objectives to include airborne fungi as an IAQ parameter as promised in 2003. The EPD stated that in the next revision of the IAQ Objectives, a guideline value of 500 CFU/m^3 would be included for airborne fungi. Research on international airborne fungi guidelines provided Singapore’s guideline of 500 CFU/m^3 and Malaysia’s guideline of 1,000 CFU/m^3 as references. From these two countries’ guidelines, a concentration of 500 CFU/m^3 seems to be an appropriate concentration of airborne fungi to be considered satisfactory. Airborne fungi should be included in Hong Kong’s IAQ Objectives as soon as possible to prevent health effects from the harmful toxins of airborne fungi.

Furthermore, it would be advisable for Hong Kong shopping mall owners to look into whether using EMF filters instead of HEPA filters in MVAC systems is feasible. Switching to EMF filters would be achievable if the dimensions of the filter fit that of MVAC systems and if the EMF filter would be able to function the same way in a MVAC system as it does in an EMF air purification system. If a shopping mall does not find that it is feasible to use EMF filters in

MVAC systems as of the beginning of year 2014, the mall should continue to stay updated on the latest developments in EMF filtration in case the filters are adjusted such that it becomes feasible in the future.

The mall owners should also keep an eye on the photocatalytic oxidation technology, especially regarding the next research studies done by Lawrence Berkeley National Laboratories. Once the technology is improved to release less unwanted by-products and is adjusted so that it can be used inside of MVAC systems, mall owners could perform a cost analysis study and decide if they want to invest in photocatalytic oxidation technology.

Furthermore, it would be advisable for the mall owners to perform a cost analysis study for the Honeywell IAQPoint2. They should determine if investing in the Honeywell IAQPoint2 or other devices that utilize Building Automation Control network (BACnet) or Modbus communication technology is worthwhile for them.

This project was an evaluation of two tasks under Hong Kong's IAQ Management Programme, the IAQ Certification Scheme and IAQ Objectives. These tasks were evaluated through the distribution of questionnaires, analyzation of questionnaire data, and research on IAQ Objectives and recent IAQ technology. The conclusions and recommendations drawn from this study will hopefully serve as resources for the improvement of the Certification Scheme and IAQ Objectives which in turn will help to improve the IAQ in Hong Kong.

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Glossary

List of abbreviations

α	Significance Level
$\mu g/m^3$	Micrograms per cubic meter
ABC	Airborne Bacteria Count
AIDS	Acquired Immunodeficiency Syndrome
AIHA	American Industrial Hygiene Association
ANOVA	Analysis of Variation
ArchSD	Architectural Services Department
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BEAM	Building Environmental Assessment Method
Bq/m^3	Becquerel per cubic meter
BRIs	Building Related Illnesses
ºC	Degrees Celsius
CFU/m^3	Colony Forming Units per cubic meter
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DBRI	Danish Building Research Institute
EMSD	Electrical and Mechanical Services Department
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
GN	*Guidance Notes for the Management of Indoor Air Quality in Offices and Public Spaces*
H_0	Null Hypothesis
H_1	Alternative Hypothesis
HCHO	Formaldehyde
HKSAR	Hong Kong Special Administrative Region
HVAC	Heating, ventilating air conditioning
IAQ	Indoor Air Quality
m/s	Meters per second
MVAC	Mechanical ventilating air conditioning
NIOSH	National Institute of Occupational Safety and Health
NO_2	Nitrogen Dioxide
O_3	Ozone
OIC	Ontario Interministerial Committee
p	p-value
$PM_{2.5}$	Airborne Particulate Matter with diameter less than or equal to 2.5 µm
ppb	Parts per billion
ppm	Parts per million
PWC	Public Works Canada
RH	Relative Humidity
Rn	Radon
RSP	Respirable Suspended Particles
SBS	Sick Building Syndrome
U	Mann – Whitney's U statistic
T	Temperature

TVOC	Total Volatile Organic Compounds
VOC	Volatile organic compound
WHO	World Health Organization
z	z-score

Appendix A: Mission and Organization of the Sponsoring Agency

Business Environment Council Limited (BEC) is an independent, non-profit membership organization, established by the business sector in Hong Kong. Since its establishment in 1992, BEC has been at the forefront of promoting environmental excellence by advocating the uptake of clean technologies and practices which reduce waste, conserve resources, prevent pollution and improve corporate environmental and social responsibility. BEC offers sustainable solutions and professional services covering advisory, research, assessment, training and award programs for government, business and the community, thus enabling environmental protection and contributing to the transition to a low carbon economy.

The purpose of BEC is reflected in its mission statement: “To advocate environmental protection amongst our members and the broader community, the uptake of clean technologies and practices which reduce waste, conserve resources, prevent pollution, and improve the environment”. BEC partners with the government to convince business leaders to implement changes that will improve the quality of air, energy efficiency, waste management, and the waterfront. BEC offers a variety of services such as advisory, research, assessment, training, and award programs to support member businesses. Various training courses are offered in subject topics of Green Building & Energy Efficiency, Indoor Air Quality, Environmental Management & Policy, Environment, Social and Governance Reporting, and Green Living. Specifically for indoor air quality (IAQ) is the first accredited Certificate Issuing Body (CIB) under the Hong Kong Inspection Body Accreditation Scheme (HKIAS) to conduct assessment, certify and audit premises under HKIAS003- IS017020.

BEC has a broad range of connections with networking opportunities with over 20, 000 businesses. BEC’s strategic direction is governed by a board of directors drawn from leading multinational and local corporations, which is under the leadership of Chairman, Prof. John Chai. The BEC's professional team is under the leadership of the Chief Executive Officer, Ms. Agnes Li. Throughout this project, we worked with Dr. Veronica Chan who is a specialist in IAQ and Programme Manager – Education. Dr. Chan teaches training courses to businesses to help improve their management of indoor air quality.

Appendix B: Questionnaires

Indoor Air Quality (IAQ) Questionnaire

WPI

Personal Information

1. Gender ☐ Male ☐ Female
2. Age ☐ < 21 ☐ 21 – 35 ☐ 36 – 45 ☐ 46 – 64 ☐ ≥ 65
3. Residency ☐ HK resident ☐ Tourist (country:_______________________)
4. How much time did you spend in this building today? ___________________________

Air Quality

1. How does the air quality in this shopping mall affect you?

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

2. How is the air flow in this shopping mall?

Too strong – 1	2	3	4 – Perfect	5	6	7 – No flow

3. How are the odours in the air of this shopping mall?

Very fragrant – 1	2	3	4 – No smell	5	6	7 – Very smelly

4. How is the humidity in this shopping mall?

Too humid – 1	2	3	4 – Perfect	5	6	7 – Too dry

5. How does the temperature in this shopping mall affect you?

Very positively – 1	2	3	4 – No effect	5	6	7 – Very negatively

6. How is the temperature in this shopping mall?

Too warm – 1	2	3	4 – Perfect	5	6	7 – Too cold

7. Have you heard of the Indoor Air Quality Certification Scheme?

Yes	No

   a. **If you answered yes to Q7**, which class do you think this shopping mall belongs to?

Good	Excellent	Uncertified	Don't know

8. **TOURISTS ONLY:** how does the air in this shopping mall compare to the indoor air of malls in your country?

Better	Similar	Worse

9. According to your personal standards, is the air in this shopping mall satisfactory?

Yes	No	Don't know

10. Rate the **indoor** air quality in this shopping mall **(1 being the best & 7 being the worst)**:

Best – 1	2	3	4	5	6	7 – Worst

11. Rate the **outdoor** air quality around this shopping mall **(1 being the best & 7 being the worst)**:

Best – 1	2	3	4	5	6	7 – Worst

12. Does the indoor air quality of shopping mall affect the amount of money you spend?

Yes	No

   a. **If you answered yes to Q12**, if the indoor air quality were improved in this mall, how would it affect the amount of money you spend? (circle one)

-90% -70% -50% -30% -10% +10% +30% +50% +70% +90%

-100% -80% -60% -40% -20% no effect +20% +40% +60% +80% +100%

13. Are you interested in courses on indoor air quality in **(check all that apply)**:
   ☐ Management ☐ Improvement ☐ Principle ☐ Standards
   ☐ Schools ☐ Shopping Malls ☐ Offices ☐ Others ____________

Additional Comments (i.e. how to promote or improve indoor air quality):

____
____
____

Figure B.1: Questionnaire English Version

室內空氣問卷調查

個人資料

1. 性別 ☐ 男 ☐ 女
2. 年齡 ☐ < 21 ☐ 21 – 35 ☐ 36 – 45 ☐ 46 – 64 ☐ ≥ 65
3. 居住地方 ☐ 香港 ☐ 遊客(國家:______________________)
4. 今天你會在這個商場花多少時間? ________________________

空氣質素

1. 這個商場的室內空氣質素怎樣地影響您?

十分正面 – 1	2	3	4 – 毫無影響	5	6	7 – 十分負面

2. 室內空氣的流通程度?

太強– 1	2	3	4 – 合適	5	6	7 – 沒有任何流通

3. 室內空氣的異味程度?

很香– 1	2	3	4 – 毫無異味	5	6	7 –異味嚴重

4. 室內空氣的濕潤程度?

非常潮濕 – 1	2	3	4 –合適	5	6	7 – 非常乾燥

5. 這商場的室內溫度怎樣地影響到您?

十分正面– 1	2	3	4 – 毫無影響	5	6	7 – 十分負面

6. 這商場的室內溫度是否過冷或過熱?

極熱 – 1	2	3	4 – 合適	5	6	7 – 極冷

7. 你有沒有聽過室內空氣質素檢定計劃?

有	沒有

   a. **如有**, 你覺得這商場的室內空氣質素得到什麼評級?

良好	卓越	未經	不知道

8. **如果你是遊客**，這商場的空氣質素比貴國的商場的室內空氣質素

好	差不多	差

9. 根據您個人評判標準，您滿意這商場的室內空氣質素嗎?

是	否	不知道

10. 請給這商場的室內空氣質素評分 **(1 代表很好 & 7 代表很差)**:

很好 – 1	2	3	4	5	6	7 **– 很差**

11. 請給這商場附近的室外空氣質素評分 **(1 代表很好 & 7 代表很差)**:

很好 – 1	2	3	4	5	6	7 **– 很差**

12. 這個商場的室內空氣質素會否影響你的消費嗎?

會	不會

   a. 如果會, 如果室內空氣質素改善了,你會花費更多嗎?

-90% -70% -50% -30% -10% +10% +30% +50% +70% +90%

-100% -80% -60% -40% -20% 沒有效果 +20% +40% +60% +80% +100%

13. 您是否有興趣以下有關室內空氣質素的課程 **(請選擇適合的)**:

☐ 管理 ☐ 改善方法 ☐ 理論 ☐ 標準

☐ 學校 ☐ 商場 ☐ 辦公室 ☐ 其他 __________

其他意見(例如:如何促進或改善室內空氣質量):

____

____

Figure B.2: Questionnaire Chinese Version

Appendix C: Summary of Inferential Statistics

Explanation of inferential statistics

"Inferential statistics are the statistical procedures that are used to reach conclusions about associations between variables" (Bhattacherjee 2012). They make conclusions, or inferences, about a population from observations of a sample. In inferential statistics, "the results of an analysis using a sample can [be] generalize[d]…to the larger population that the sample represents" (Crossman, 2014). Inferential statistics "are explicitly designed to test hypotheses" (Bhattacherjee 2012). Hypotheses can only be rejected with contrary evidence and also cannot be accepted. Because a hypothesis of interest, or an alternative hypothesis, cannot be accepted, a null hypothesis is created as the opposite of the alternative hypothesis. Evidence is used to reject the null hypothesis to support indirectly the alternative hypothesis. Inferential statistics are never deterministic but always probabilistic because the dependent variable could be affected by many extraneous factors (Bhattacherjee, 2012). The statistical tests described in the methodology are based on inferential statistics.

Explanation of descriptive statistics

Descriptive statistics are statistical procedures that visualize, describe, or summarize data (Crossman, 2014; Laerd Statistics, 2013b). Descriptive statistics include measures of central tendency and measures of spread. Measures of central tendency describe "the central position of a frequency distribution for a group of data" (e.g. mean, median, mode) (Laerd Statistics, 2013b). Measures of spread summarize "a group of data by describing how spread out the scores are" (e.g. range, quartiles, range, variance, standard deviation) (Laerd Statistics, 2013b). Descriptive statistics can only describe the data collected and cannot make any conclusions past the data (Crossman, 2014; Laerd Statistics, 2013b).

Explanation of statistical terms:

Significance level (α)

The significance level, α, is "a fixed probability of wrongly rejecting the null hypothesis…if it is in fact true (Easton & McColl, n.d.a). In other words, it is "the maximum level of risk that we are willing to take that our inference is incorrect" (Bhattacherjee, 2012). The standard convention is to set the significance level to $\alpha=0.05$ (Easton & Mccoll, n.d.a).

p-value (p)

The p-value, or p, is "[t]he probability that a statistical inference is caused [by] pure chance." If the p-value is less than the significance level $\alpha=0.05$, there is "enough statistical evidence to reject the null hypothesis and thereby, indirectly accept[ing] the alternative hypothesis." If the p-value is greater than $\alpha=0.05$, there is not enough statistical evidence to reject the null hypothesis (Bhattacherjee, 2012).

Independent variable & dependent variable

"In an experiment, the *independent variable* is the variable that is varied or manipulated by the researcher, and the *dependent variable* is the response that is measured. An *independent variable* is the presumed cause, whereas the *dependent variable* is the presumed effect" (Collier, n.d). The dependent variable is a variable that depends on an independent variable (Laerd Statistics, 2013g).

Independent sample & dependent sample

"Independent samples imply that the choice of subjects for one group, or sample, does not depend on who is in the other group, or sample. Dependent samples occur when there is a natural matching between the subjects in one sample and the subjects in the other sample." For example, if the same individual is surveyed at two different malls, the scores for the two malls would be dependent (Harring, n.d.).

Null hypothesis (H_0) & alternative hypothesis (H_1)

"The alternative hypothesis, H_1, is a statement of what a statistical hypothesis test is set up to establish." "The null hypothesis, H_0, represents a theory that has been put forward…because it is to be used as a basis for argument, but has not been proved" (Easton & McColl, n.d.a). H_0 for Objective 1 of this project is that people cannot distinguish a difference in IAQ of certified and uncertified malls. H_1 is that people can distinguish a difference in IAQ of certified and uncertified malls. The results of the statistical tests are always shown in terms of the null hypothesis. H_0 is either rejected in favor of H_1 or is not rejected. If H_0 is not rejected, "this does not necessarily mean that the null hypothesis is true, it only suggests that there is not sufficient evidence against H_0 in favour of H_1." If H_0 is rejected, this means that the H_1 might be true (Easton & McColl, n.d.a).

Variance

"The (population) variance of a random variable is a non-negative number which gives an idea of how widely spread the values of the random variable are likely to be; the larger the variance, the more scattered the observations on average." Variance is the squared value of the standard deviation (Easton & McColl, n.d.b)

Post-hoc test

Post-hoc is a Latin phrase meaning "after this." Post-hoc tests are performed after tests that determined the distribution of groups are statistically different. The post-hoc tests determine which pairs of values are statistically different from one another (Fernald, 2012)

Parametric test & nonparametric test

"A parametric statistical test is one that makes assumptions about the parameters (defining properties) of the population distribution(s) from which one's data are drawn, while a non-parametric test is one that makes no such assumptions." Some parametric tests, such as t-tests and ANOVA, assume that the source population is normally distributed. A non-parametric test does not make such assumptions. Some examples of non-parametric tests are the chi-square test for association, Kruskal-Wallis test, Wilcoxon-Mann-Whitney test (Lowry, 2013b).

Outlier

"An outlier is an observation that lies outside the overall pattern of a distribution" (Renze, 2014)

Cross Tabulation

A cross tabulation, also known as a contingency table, is used to analyze categorical data. It is a two dimensional table that records the frequency of response (Qualtrics, 2011). Examples of cross tabulations are Tables 4.17 and 4.19.

Mean Ranks

Mean Ranks are used in the Mann-Whitney test. In determining mean ranks, all the values are ranked from low to high, disregarding to which group each value belongs. The lowest value is assigned a rank of "1." The greatest number is a signed a rank of "n," where "n" is the total number of values in both groups. The ranks are averaged in each group, and the averages are the mean ranks. If the mean ranks of both groups have a large difference, the p-value will be small (GraphPad Software, 2013).

Explanation of statistical tests

Analysis of variance (ANOVA)

The one-way ANOVA a statistical test used to determine whether or not there are statistical differences among the averages of three more independent groups. However, the one-way ANOVA cannot determine which groups are statistically different, and Tukey's HSD test is required to do so (Laerd Statistics, 2013f). ANOVA assumes that the dependent variable has propertied of an interval scale; that the samples are randomly and independently collected from the population; that each group's data are normally distributed; that the groups have approximately variances; and that there are no outliers in any of the groups (Laerd Statistics, 2013a; Lowry, 2013a).

Tukey's HSD test

The Tukey's HSD test is a post-hoc test that is conducted after there are statistical differences found among the groups by ANOVA. The Tukey's HSD test determines which two groups are statistically different (Laerd Statistics, 2013f).

Kruskal-Wallis test & pairwise post-hoc test

"The Kruskal-Wallis test is the non-parametric alternative to the one-way ANOVA and is used to determine whether there are any statistically significant differences between the distributions [or medians] of three or more independent (unrelated) groups." The only assumption for the Kruskal-Wallis test to give a valid result is that "the shape of the distribution of scores in each group should be the same" or similar. If the Kruskal-Wallis test determined that there are significant differences, a pairwise comparisons post-hoc test was conducted to see which pairs differed (Laerd, 2013d).

Independent t-test

Similar to ANOVA, "[t]he independent-samples t-test is used to determine if a [statistical] difference exists between the means of two independent groups on a continuous dependent variable. The independent sample t-test assumes that the variable is continuous and dependent; that the independent variable is categorical with only two groups, that the samples were independently and randomly selected; that there are be no outliers in the two groups of the independent variable with respect to the dependent variable; that the dependent variable is approximately normally distributed for each independent group; and that the variance is the same in each independent group (Laerd, 2013c).

Chi-square test for association

"The chi-square test for association tests for whether two categorical variables are associated. Another way to phrase this is that this test determines whether two variables are statistically independent" (Laerd, 2013a). The assumptions chi-square test are that the two variables being tested are nominal; that there are two or more groups in each variable; that each sample is independent; and "that no more than 20% of the expected counts are less than 5 and all individual expected counts are 1 or greater" (Laerd, 2013a; Weaver, 2013). If the p-value is less than the significance level, then there is a statistically significant association between the variables (Laerd, 2013a).

Mann-Whitney U test

The Mann-Whitney test is the non-parametric alternative test to the independent-samples t-test. The assumptions of the test are that there are only two variables, one dependent variable continuous or ordinal and one independent variable that has two categorical and independent groups; that the samples were independently and randomly drawn; and that the distributions for both independent groups have similar shape. The test determines if a statistical difference exists between the medians of two independent groups on a continuous dependent variable, if the assumptions are not violated. If the only assumption that distributions of the two groups are similar is violated, the test determines whether the mean ranks/distributions are statistically different (Laerd, 2013c).