Rise to the Challenge

Vertical Farming within the Urban Environment
Master's Thesis Explanatory Document
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A research project submitted in partial fulfillment of the requirements for the degree of masters of Architecture Professional.
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There has been a rapid increase in the world’s population in the last one hundred years with the total world population increasing from 1.65 billion to 7.5 billion. Population rise has caused city sprawl, higher density living and increased demand for both food and jobs. Due to the increase of the population, our carbon footprint and impact on the environment has increased exponentially. Pollution and global warming is the direct result of population growth and consumerism. With agriculture being the highest form of pollution (methane gas) we need to review the way we look at farming with more input on design and planning. Global warming and climate change have become a major concern in today’s day and age. We need to start designing with little to no impact on the environment, with passive and sustainable architecture at the four front of the development.

This research proposal aims to:

- Introduce a new type of farming system that is both modern and self-sustainable into New Zealand.
- Understanding and gaining a wider knowledge on the necessary steps needed for Vertical Farming to be applied to New Zealand as a growing country.
- Produce a well thought out architectural building, designed to display the entire overall outcome of my findings on Vertical Farming within New Zealand. It is important we allow form, functionality and efficiency to drive the design.
- Reviewing farming practices as they are today and re-interpreted how we see farming.

As a growing world, it is imperative to review these current processes and make them more efficient and less destructive to the environment. The overall outcome this project will focus on, is to positively integrate the Vertical farming aspect into the urban environment in Auckland. The proposed project is a Vertical Farm facility that encourages education and research for both students and the public about modern age farming. The vertical farm specific to this project can be defined as not only an educational facility but one that grows and produces plant products.
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1.0 Introduction

1.1 Research Question

How can Vertical Agriculture be integrated into the urban environment on a large enough scale to benefit Auckland City?
1.2 Project Outline

The proposed project is a Vertical Farm facility that encourages education and research for both students and the public about modern age farming. The vertical farm specific to this project can be defined as not only an educational facility but one that grows and produces plant products.
Figure 1: Diagram of growth
1.3 Research Problems

As the world’s population grows and technology advances and evolves, the way we live is changing. Farming has embraced these new technologies and processes that are now becoming more mainstream. These new farming technologies help with everything from selecting and developing the largest, tastiest vegetables, to using chemicals to reduce pest damage on produce. As we enter an age of larger city populations, deforestation and technology dominated environments, crop farming systems are having to change to keep up with demand, pricing, and climate change.

By 2050, the world population is projected to be at nine billion people. At the current 2017 world population sits at 7.5 billion people, this growth equates to approximately 4.5 million people per year. This rapid population growth will impact both economically and socially on current infrastructure, food supply, resources and usable land area. Negative environmental and economic outcomes will arise in the cost of food, lack of fresh water, global warming and waste production.
The current horizontal farming model can be seen as inflexible with the current modern movement. I intend to introduce the vertical stack system as an alternative to the horizontal sprawl system on which New Zealand farming is currently based. The vertical stack system requires less floor area but contains the same space as a large horizontal farm. Sprawled farming has a smaller margin of product yield and a larger pollution output as opposed to vertical farming which is far more sustainable and efficient, with less resulting pollution.

As there are no existing buildings of this typology in New Zealand, I will need to draw most of my data from current books, technological data and other countries which have either developed actual buildings, or concepts for such buildings. Vertical farming is not a new concept, however, where the concept has been actualized, architectural design is lacking. The buildings which function as vertical gardens tend not to have any aesthetic qualities. Most companies put their money into the operations within, rather than their aesthetic. The current model look is large warehouse-like facilities, which are referred to as factories rather than farms.
Although the existing buildings have low aesthetic worth, there are research studies of and proposals for large urbanized vertical farms that are architecturally and functionally designed to achieve a symbiosis with the urban environment. However, while information can be drawn from both existing and proposed examples, there will still be limitations and accordingly, assumptions will have to be made which will influence the design outcome. The intent is to design a vertical building within an urban context of office towers that is not only contextual but more beautiful than the existing skyscrapers.
Figure 2: Horizontal Land to Vertical Land
1.4 The Scope of Limitations

Limitations:
Engineering and other Consultants: As this is mainly a design based project, the fundamentals of the final building will be in concept only. An engineer will be consulted about the conceptual basis of structure, but not the detail. As for consulting builders and other contractors, this falls beyond the cost and timeframes of the project, therefore, limiting any assessment of the overall viability of the vertical farm design within New Zealand.

Costs: As per the information above accurate calculation of the overall cost of the building will be limited due to insufficient data pertaining to existing building typologies within New Zealand. Estimates will be made by running costs for similar buildings.
Assumptions:
Production numbers: As there are no existing buildings of comparable size and structure in New Zealand, I will have to assume product yield, along with the frequency of yield per year. Productivity will be assumed based on the number of trays, units and plants and the effect of turnover per unit. For example, a unit of 5 trays with five plants harvested 5 times per year would give a yield of 125 plants per year overall. Accordingly, building viability will be gauge based on assumed production by calculating the numbers in this way, give or take some failed plants during the initial stages. These assumptions will also depend on the type of crop as each crop has a different growth cycle.

Sales: Unfortunately, it is close to impossible to predict the level of product sales that will occur as plants have not previously been grown in New Zealand in this way. I will, therefore, assume at this point that 90% of produce will sell.
This project aims to integrate the rural farming model into the urban environment of Auckland City. The biggest positive of this integration will be access to fresh locally grown produce on a daily basis. Imported fruits and vegetables use up valuable resources, whereas if these products are available in our cities, both money and resources will be saved. Farming has evolved over time, and there are different types of farming models in use within Auckland. Land-based farming and greenhouses are two common types. The objective is to look at these two large-scale farming models as a reference for how we can improve and integrate vertical farming into New Zealand. By comparing the proposed model to models currently in use in cities all over the world, I can better understand and design for the best feasible way of integrating the farm into the city.
1.5 Aims and Design Objectives

The goals I am hoping to achieve are:
• Create a new farming model for the city as an alternative to the current farm on the outskirts of the city
• Produce easily accessible, fresh food
• Create a well-integrated facility for farming in an urban environment
• Reduce the impact of farming on the New Zealand environment

The architectural design process will follow the basic methodology, as outlined above. As the project progresses and changes due to limitations and design choices, the methodology will also change in response.
1.6 Methodology

The methodology for this project is a combination of findings from leading researchers on vertical farming and current vertical farming systems. To a large extent, the design will be based on information gathered from the research methods described. A combination of existing and proposed systems and designs will inform the final design outcome.
This document follows the three-stage process.

(i) Research and analysis: Research existing literature on the subject, including journals and applied designs and buildings in current use. Precedent studies on a global level will give basis to applying the research to my design. Analyzing the existing buildings against the literature will allow me to see what is working and what is applicable to Auckland City. It will also open up possibilities for alternative solutions to my design.

(ii) Massing and Planning: This part will mostly be based on exploration based on the research and analysis. Exploration in terms of form, aesthetics, function, and integration. Exploration of what combination of form, function, and aesthetics works well.

(iii) Response and findings: This part of the project will revolve around understanding and by trial and error of iterations in regard to the overall design decisions, and what the building will require in terms of running systems. The findings from this stage of the research will dictate most of the systems selected. Any negative findings will be reflected in changes to my design response in relation to the systems specified.

Design for the application to Auckland City: The outcome will hopefully be a coherently integrated design for Auckland City. All design decisions will be guided by previous research findings and responding to issues identified in the second stage of the project.
1.7 Summary

Vertical farming is a relatively new form of architecture. Despite the experience in the subject of vertical farming, it is taking many countries by storm, with Japan, America, and Indonesia leading the world in innovative forms of vertical farming. Research on the current construction, design, and technology used in these structures will help when trying to apply similar systems to Auckland City.

Figure 3 a: Research Problem Diagram

Figure 3 b: Hydroponic System Layout
2.0 Global Farming

2.1 Introduction

In response to the public health, economic and global warming issues among others, agriculture has moved from the outskirts of towns into the city itself. Urban agriculture is now becoming very common around the world. Due to the ways, cities are structured, with tall buildings, concrete everywhere and lack of open spaces for gardens and orchards, urban agriculture has found ways of making the growing process simpler and more efficient. This is known as Z-farming or Zero-Acreage Farming, where there is no use of farmland or open space. City greenhouses, rooftop gardens, green walls and indoor farms (vertical farms) are ways of producing more sustainable, efficient, cheaper food.
2.2 What Plants Need

To understand what farming is, one needs to understand what a plant requires to grow. The growth of a plant begins with a seed or a seedling cut from an existing plant. This seed or seedling is then placed into a growth medium to support and protect the plant and this also helps it to survive in unfavorable weather conditions. The plant requires water and nutrients to grow. The nutrients supply fuel for the plants to grow and all living things on earth require water. Another very important resource plants require to grow is sunlight. Plants are the only species on the planet able to photosynthesize.

Photosynthesis is the process by which CO2 (carbon dioxide) is processed and changed into O2 (oxygen), which is then released as a waste product. This is why we have oxygen on our planet. The plant requires the energy harvested from the sun to break apart the molecular bonds of carbon dioxide to release oxygen. The plant uses the resulting carbon particles for growth including fruit and vegetables which come from the ground and end up on the plate.

Accordingly, plants require four main resources to grow efficiently. These are water, nutrients, carbon dioxide and sunlight. The indoor farm requires these four systems to function at a very efficient level so that the plants can grow just as efficiently as outdoors.
2.3 History of Farming

Farming has been around for thousands of years. Four million years ago the first hominid species learned how to forage for food, which marked the beginnings of village life as society separated into hunters and gatherers. As weather conditions became more stable groups of early humans began to plant and produce food in the areas they lived. The earliest estimation of the first human farmers is twelve thousand years ago and the start of global agriculture dates from 1650 AD, although not as we know it today. Early farming was mostly done by hand, and if the produce never made it through the weather conditions, that was that for the farmers. Farming practices have shown progressive development through the ages, from farming using hand-held tools, to the oxen driven plow, and onto the tractors and other machinery used to plow the fields to release nutrients so the plants have a food source.
Developments in the way we farm and the tools we use, have resulted in changes in the location of where we farm. Early humans would farm on the same piece of land they lived on, whereas now farming activity occurs far from where most people live. As the world progressed and larger groups of people gathered in one area, they began needing land for purposes other than farming. As a result, farming was pushed to the outskirts of the livable land. The rise of towns and cities pushed farming into more rural areas. This is the norm in most countries, as the city is a place where living, work, and entertainment are packed into a dense area. Traditional farming requires large pieces of land which do not fit with modern day urban environments. However, just as we have learned to accommodate more on less land by extending upward in vertically stacked systems for a living, working, and entertainment, why not do the same for farming?
Figure 6 gives an overview of land used globally for farming processes. The amount of land currently used as seen in the image is vast. As seen in the image the darker colours are countries where farming has a larger land distribution. We can decrease this by changing the sprawl of farming to a stacked vertical form of farming.
The world population to food production numbers have always moved parallel to each other. The attached graph shows how they relate to each other. As the population increases so do our food demands.
2.4 Agriculture and Architecture

Farming and buildings have always gone hand in hand. Agricultural buildings range from the humble farm shed or barn to the modern storage sheds we have today. According to James Dawe in his master’s thesis Farm Buildings and Architecture, the enduring links between agriculture and architecture in the form of humble and functional farm buildings are being lost. He demonstrates how agriculture and modern-day architecture can come together in a well thought out design for both sustainable, ethical and aesthetic agriculture.

In relation to farming, agricultural architecture has a functional rather than aesthetic aspect. Over the years farm buildings have transformed from a common shed-like building to more of a factory based facility. These facilities are becoming more and more sustainable and efficient. In the book Of Woolsheds, Houses, and People, New Zealand farming architecture is described as ‘the only building that we have all had a hand in – that’s grown out of our needs, our requirements, our kind of way of living. Everyone’s had a hand in it – Maori and European –especially on the East Coast. It has a particular kind of form and function’.

Figure 8: Farm House Examples
Although standard farmhouses and large sheds are still seen in most countries, there are larger companies in countries like Japan, America, and Turkey that have developed large factory-like facilities that focus on plant/vegetable production. These facilities are commonly large shed-like buildings. However, places like Singapore and Bali are proposing new types of architecturally designed facilities focused on sustainable crop production. By developing similar types of facilities, we can conserve our resources and improve the price and the quality of New Zealand vegetables and fruit.
Global farming practices have long been upgrading and moving forward. The current innovations have brought farming into the modern age; architecture and agriculture are becoming more and more intertwined. Now as a new multi-story high-rise goes up in a city, sustainability, green roofs, and internal greenery are taken into consideration. New Zealand needs to move forward with the rest of the world and upgrade our approach in order to stay relevant in the farming industry.

2.5 Summary

Figure 9: Food travel

Figure 10: Aeroponic System
3.1 New Zealand Farming

For thousands of years now farming has always been a huge part of the New Zealand way of life and economy. Early Maori grew plants such as kumara, ti, taro and Aute. The early Maori would plant and cultivate the land they lived on within the same spaces they lived. Plants were then harvested and stored in living areas or underground. It is also a believed that early Maori cultivate some plants because of their beauty, as plants such as Kaka beak and Napuka are commonly found around the locations of early Maori settlements. The Maori understood that it was better to live alongside the plants and agriculture they produced in order to function as an effective community. Food was easily accessible and crop production could be monitored to meet the demands of tribal growth.

New Zealand’s soils and temperate climate made farming a viable prospect for New Zealand’s colonial settlers. When the early Europeans settled in New Zealand, they brought with them the traditional method of farming we are all familiar with today. But due to the growth-friendly, the climate in New Zealand, the settlers population grew, as well as more settlers joining the new colony. In turn, the farmers required more land to plant more crops. Farms were therefore moved to the outskirts of small towns. As these towns developed into cities, farms were then moved further away from the cities to the outskirts.
Farming has always been a huge part of New Zealand's economy. ‘Because New Zealand was founded on agrarianism, old farm buildings have become a memorial to the early colonial economy,' writes Geoffrey Thornton, explaining the link between agriculture and New Zealand's economic foundations.

Agriculture contributes two-thirds of New Zealand’s exports, earning the country $14.8 billion. The National Government recently established irrigation subsidies. A total of $400 million of public funding will be spent on providing water to benefit farmers. A large amount of land in New Zealand is currently used for farming.
Field crop growers in New Zealand

By region, 2013, number of people employed

Provider: Stats NZ

Figure 12: Field Crop Table New Zealand
Figure 13: New Zealand Outdoor Vegetable Types

The table above describes the land used in plant farming in different areas in New Zealand, with Canterbury being the largest area in which we grow plant products. In 2007 54.8 % of the Land in New Zealand was used for farming. However, there has been a steady decline in farmland areas, from 2002 to 2007.
Field crop farm workers in New Zealand

By region, 2013, number of people employed

Provider: Stats NZ

Figure 14: New Zealand Field Farm Workers
There are many jobs generated by the farming systems we currently have. Many people fear removing current forms of farming will impact the economy and reduce the number of jobs for the general rural population. However, vertical farming will simply relocate the jobs into more densely populated areas, not to mention providing safer and cleaner working environments for the workers.
3.2 Current Farming Practice

Listed below are the different systems of farming we currently used in New Zealand:

Greenhouse Model
Greenhouse farming is classed as an indoor model of farming. Greenhouses are generally constructed of glass and steel. The glass panels are transparent to allow the sun to pass through. The indoor space of greenhouses is considerably warmer than outside, as the sunlight that enters through the glass is absorbed and then reflected by the soil and plants, keeping the space warm. This is important because plants that require warm conditions can be grown all year round and plants not common to New Zealand can also be grown in the warmer microclimate provided by this indoor growing system.

As with plants grown outdoors, greenhouse plants require irrigation, nutrients, sunlight and a planting medium. Standard greenhouses contain planter boxes with a soil based medium. The sunlight enters through the transparent panels and 90% the radiation is used in photosynthesis, allowing the plants to grow as if they had almost the same exposure as being naturally grown in the sun. This system provides protection from the weather as well, increasing the yield of the crop to 90% of overall planted.
Outdoor Farming Model
Outdoor farming is exactly as it says. Plants have been growing outside naturally for millions of years. Over time human beings have devised ways to farm fruits and vegetables and thereby control their natural production. The current farming model consists of large quantities of fertilizers and chemicals used to protect and help grow the plants. Mechanical irrigation systems are used to provide water while pesticide and chemical sprays are used to ensure less insect damage, and a better looking and larger crop. Conventional farming uses up to 70% of the natural freshwater supply.

This current model is possibly the most common and the most inefficient as it creates the most issues within the systems used. Along with the pesticides and chemicals used, farmer requires large areas of land to make this system viable and profitable. These large areas of land are almost always located on the outskirts of towns and far from cities, making the transport costs and food miles further than they need to be.

Forest Farming
This form of farming involves the cultivation of plantations of trees such as pine and eucalyptus. The New Zealand timber industry depends on the farming of such timbers for building and economic growth. This form of farming is considered a cleaner, a more sustainable form of farming as the same land is planted, harvested and then re-planted. This sort of farming provides forestation on a recycled basis. Forests such as Riverhead in Kumeu and Woodhill forest are just two local examples of commercial pine forests which allow public access to trails and tracks.
Figure 15: Farm Land New Zealand
3.3 The Current Negative impacts of New Zealand Farming

i. Clean, Green New Zealand (Agricultural Run-Off)
New Zealand labels itself “clean and green,” promoting a natural, green, organic image to the rest of the world. However, in reality, we are far from this. Agriculture alone produces 49% of the total energy emissions in New Zealand. Emissions from agricultural sources alone have increased by 23% since 1990. In 2014 gross emissions under the United Nations Framework Convention on Climate Change were 56.7 Mt CO2-e. Also, in relation to vehicle emissions, New Zealand has one of the highest rates of car ownership per person globally, at 740 cars per 1000 people.

ii. Population Increase
Since 1990 New Zealand has experienced a massive population increase in relative terms. This is due to economic growth and job opportunities leading to an increase in the number of immigrants. The population has grown from 3.3 million people in 1990 to 4.6 million people at the last census, and we are still growing at a rapid rate. Auckland is New Zealand’s largest city at 1.5 million people, roughly 32% of the total population of New Zealand.
iii. Healthy food costs
Over the last decade, fresh vegetables in New Zealand have become expensive and unaffordable for many. It is now cheaper to buy a value meal at McDonald’s than it is to purchase a bag of tomatoes or spinach. Many factors dictate fresh food prices. Things such as labour, transport and importation add to the rising prices. Local farmers and small farm owners tend to sell their produce on the side of the road or at a local farmers market for cheaper prices, cutting out the transportation costs. Many people are happy to buy this produce as they are looking for cheaper, healthier options. Cutting out transport costs by providing locally grown produce in the farm-to-table approach will both support our economy and reduce household food costs considerably.

iv. Food miles
One of our primary traders is our neighbour Australia. A large amount of produce is traded between our two countries. However, a larger amount of the vegetables and fruit available in New Zealand come from even further away, from countries such as China and America. Imported fresh produce is harvested before its time, the food then ripens on the journey, and by the time it arrives in our supermarkets some of it is already overripe and not suitable for consumption and therefore is thrown away. Food that ripens off the tree is less tasty as it is not receiving the full amount of nutrients. It does not ripen correctly and is not fresh when it reaches the table.
v. Crop Borne diseases
Vegetables and fruit host many crop borne diseases, including listeria, spotted wilt, mosaic and curly top just to name a few. There is a danger of diseases not already present in New Zealand being imported along with plants and causing problems for agriculture here. Growing more and a greater variety of produce in vertical farms would reduce the necessity to import food. Further, most diseases are caused by fungus, insects or airborne viruses. In vertical farming, the air conditions and the pests are controlled, therefore removing the danger of diseases.

vi. Pesticides and growth hormones
Many farming facilities use pesticides to protect their produce from harmful pests. Although they are successful, there are potential side effects for humans associated with the use of man-made chemicals, such as nausea, vomiting, diarrhoea and stomach cramps. Severe reactions can include chest pain, breathing difficulties and muscle pain. Although rare, harmful effects from pesticides and growth hormones are something we should be worried about as these chemicals can accumulate at dangerous levels in the environment and in our bodies.
vii. Climate change
Climate change is a big factor in farming. Greenhouse pollution from carbon dioxide and methane accumulate in the atmosphere trapping heat from the sun around the earth. The effects are hotter and longer summers and rising sea levels from the melting ice caps. This, in turn, affects weather patterns and the growth of outdoor crops. On top of this, is a weaker spot in the ozone layer over New Zealand. This hole in the ozone is not a result of greenhouse gases from New Zealand, but the effects of general worldwide pollution. The higher temperatures and extreme weather events are in part caused by agricultural run-off and farming chemicals released into the atmosphere. The idea of indoor/urban farming is to remove the chemicals from the equation and to make it safer for us and the environment.
viii. Deforestation
New Zealand has gone from 80% forest coverage during the early settlements (1000AD), to 24% today. Large areas of forest have been destroyed to create farmland. We have also cut down our native forests to provide building materials and to clear plots of land for cities and other residential areas. Precious timbers such as kauri, tawa, rimu and red beech timber are only grown in New Zealand. If we were to convert land used currently for farming into forestry, we could raise our percentage of forest and reduce negative effects caused by farming. As well as increase the native tree populations within New Zealand.
ix. Freshwater supply
There is over 425,000 km of rivers and streams in New Zealand, as well 4,000 Lakes and 200 underground aquifers. We primarily receive our fresh drinking water supply from these sources. While the average human uses 145 million litres per year, 70% of our annual freshwater collection is used for farming. Large farms have large irrigation machines that supply copious amounts of fresh water to grow produce and grass for stock. Vertical farming or urban farming systems collect and re-use fresh water. The water is put through a looped system where the water is filtered and nutrients added for direct delivery to the plants.
3.4 Predictions for the Next Five Years

Auckland City Master Plan and the Unitary Plan
Over the next ten years, Auckland CBD is expected to go through a rapid public and private infrastructure changes. Auckland City Council has scheduled a $4 billion investment in public infrastructure and $10 billion for the private industry. One of the main infrastructure projects is the city rail link which is currently underway. Plans to improve the city centre have been around since 2012. The 2012 City Centre Master Plan shows a 20-year plan for developing Auckland’s CBD. The population is due to increase over the next 20-year period, with an additional 45 000 residents and 140 000 jobs forecast for the city centre by 2032. Factor 9 of the Auckland City Centre Master Plan is around progressing sustainability, including plans to reduce the greenhouse gases by 40% overall (based on levels from 1990). However, the city plan also states there is a proposal to move food production to the outskirts of town. Contrary to this, the aim of my project is to place a food production facility right within the city centre.
Figure 10: Some of the Processes of Farming.
In the course of my research into New Zealand agricultural systems, I have identified four common negative features, which if changed will result in a better way of farming. The key issues that can be addressed to make a change for the better are:

1. **Transport:** Many farms are located on the outskirts of cities, and some are not even in the same town or region as the area the food is transported to. By moving the site of food production to the area it is needed, we can cut out the transport. Another transport related issue is that 5% of all exports from New Zealand are fruit and vegetables, thus forming an important part of our economy. While we can take steps to reduce the food miles for produce sold here in New Zealand, unfortunately, there will still be a large amount of transport required to export our produce overseas.

2. **Irrigation and Water Use:** As mentioned before we use a large amount of our fresh water on agriculture. Reducing land-based agriculture in favour of vertical farming will, therefore, be more environmentally sustainable and lead to more efficient food production.

### 3.5 Conclusion
3. Pesticides and chemicals: Land-based growing requires heavy use of chemicals and pesticides to promote growth and create good-looking produce. By cutting out this requirement, we can create healthier and chemical free produce which is better for people to eat.

4. Farm Waste: The runoff from chemicals used in crop farming is harmful to the environment. The pesticides sprayed in one area often move to other areas killing insects and wildlife in the process. Other than chemicals, there are also the stalks and stems of harvested plant products, which are commonly thrown out rather than composted to provide nutrients for the soil. We need to take steps to address these issues, as depicted above, or better yet re-design farming systems to create a safer and more efficient farming model.
Figure 18: Removal of negative systems.
4.0 The Vertical Farm
Crop farming in New Zealand has gone through many changes during the last decade. These changes range from upgrading farms to greenhouses, to using various breeding practices to produce products with additional sweetness and size. New Zealand produces a large variety of fruit and vegetables, grown both indoors and outdoors.
4.2 Literature Review

The book: “The Vertical Farm” by Dr. Dickson Despommier offers an in-depth look at high-rise farming to feed urban communities. It is currently the leading piece of literature on the urban farm. The book itself is an “all in one guide”. The author discusses the current state of agriculture, predominantly in America, and talks about the remodeling of nature in a way which we can evolve agriculture to be gentler on the environment. His idea of replanting current farmland is supported by the fact that carbon levels will reduce in areas with large carbon footprints: “The regrowth of the forests would eventually sequester significant amounts of carbon from the atmosphere and begin the healing process.” He believes that once one country adopts this technique, other countries will follow. He calls this the “my dog is bigger than yours” effect, whereby countries will want to boast about their forward movement on the subject.

Along with all the theory, he has thrown in a few examples of projects that have applied these techniques and strategies scientifically. He mentions companies like “Spread Co” in Japan and Plant Lab in the Netherlands.
The Sustainable Eco-City

(employs cutting-edge technologies)

Figure 20: Sustainability Model
The Book: “Plant Factory” - An Indoor Vertical Farming System for Efficient Quality Food Production, by Toyoki Kozai, Genhua Niu, and Michiko Takagaki; This book presents a basic outline of vertical farming systems. These systems are explained from an economic and technological viewpoint as opposed to Despommier’s theoretical approach.
The main discussion stems from the overview and comparison of techniques used in different countries in relation to economic and efficiency factors. The main focus, however, is in similarity with my project program, which is to limit the transport of perishables and fresh food over a long distance to Urban areas.
These two books along with the various websites and papers I have mentioned in the research represent the bulk of research on current day vertical farming. Factors such as the technology and attitudes to vertical farming are constantly changing, therefore current papers and websites have been my main sources.

Papers such as, “Farmland biodiversity: is habitat heterogeneity the key & quest” by Tim G Benton, Juliet A. Vickery and Jeremy D. Wilson, and “Farming and the Fate of Wild Nature” by Rhys E. Green, Stephen J. Cornell, Jorn P. W. Scharlemann, and Andrew Balmford discuss current issues and perceptions relevant to this project. These papers discuss the effects of farming on nature and find solutions to this in which farming process’ such as intensified farming is proposed “This data shows that farming (including conversion to farmland and its intensifying use) is the single biggest source of threat to bird species”

In summary, the literature review shows the problems of current farming, the solutions that might improve the current model and also the problems with other solutions and how to possibly solve them. This gives me a good basis on which to start my proposal.
Many people who have heard of vertical farming see it as a futuristic system. However, many practices used in vertical farming are commonly used today in other applications, such as hydroponics, aeroponics and drip irrigation seen in large greenhouse facilities. Indoor farming is now a safer and easier way of producing plant products, at the same time eliminating factors such as chemicals and agricultural runoff. It is also a great way of bringing farming closer to our cities thereby reducing food miles and resulting in fresher and healthier food for the table. Listed below are both negative and positive aspect on vertical farming.
Negative Aspects:

Pollen Allergies

Having plants in an indoor area means the pollen which would usually be dispersed into the air will be retained within the building, thereby exacerbating the symptoms of people with pollen allergies. However, this issue could be solved with over the counter anti-histamines and controlled selection of plants.

Uses of Resources

Traditional farming uses up to 70% of the freshwater supply every year. In vertical farming based on hydroponics, water savings of 70–95% have been calculated. The recycling and reuse of water are where the bulk of the savings are made. However, in the traditional farming model, 90% of the energy used by the plants is provided by the sun. In vertical farming, the bulk of the radiant light is provided by LED lights. This is a drain on the electrical supply. One proposed solution is to put photovoltaics on the roof of the building. However, to supply a 100m² area with enough electricity, you need a 500m² area of photovoltaics. Therefore, this is a negative aspect of vertical farming. While we will save on water, we use more electricity.
Taste and Quality
Many current plant products produced by the hydroponic process are described as “tasteless” and “watery”. As there is no soil used, many people believe that this is what changes the taste within the plant. However, with the modern technology, we have at our fingertips we can now improve the taste of the plants by fine-tuning the nutrients supplied to the plant. So yes – in the past the plants were tasteless. However, now researchers are working towards controlling the taste of each plant produced.
Positive Aspects:

Ecological Restoration
By farming within a smaller footprint, we are freeing up the areas in which traditional farms are located; this area will now have the potential to return to its original ecological state. Vertical farming within the urban environment allows for a smaller footprint, but a large vertical scale of farming. It may be possible that in the foreseeable future, the old way of farming will be rendered obsolete, and therefore more of New Zealand could be returned to the forest.

More Jobs
Vertical farming requires a lot of personnel, not just for the growing, but also for management, research, and quality control. The harvesting process alone will require a large workforce, as the typical harvest is 2000 / 3000 plants per yield for a medium sized farm. This alone should produce job opportunities.
Control of Produce
Quality control is highly important within the vertical indoor farm. The yield, taste, and appearance of the plants produced are constantly monitored for the best overall product. Within an indoor farm, it is easier to monitor product. Researchers and quality control workers can keep tabs on these factors that allow for a better overall plant.

Improved Air Quality
Plant life is well known to reduce the level of CO2 emissions as plants use CO2 in the process of photosynthesis, producing O2 (breathable Oxygen) as a by-product. Increased O2 will improve air quality within the building. As well as CO2 reduction, plants also reduce airborne VOC (Volatile Organic Compounds), thereby reducing the number of airborne infections and naturally cleaning the air.

Higher Yield
As well being able to control air quality control, growing plants within a building alleviates the effect of adverse weather conditions. The sunlight and rain you would have in an outdoor farming model are substituted by LED lighting and hydroponic water supply. The soil, from which the plant gets all its nutrients are replaced by the nutrient-rich water supply fed to the plants. By removing out the weather aspect, we create optimum growing conditions and thus more yield.
Health and Safety
By having an internally controlled environment, we also negate the need for herbicides, chemical fertilizers, and pesticides commonly used to protect and strengthen plants. This, in turn, means there is no agricultural runoff from pesticides and herbicides.
4.4 Case Studies

The analysis of previous designs is organized into four categories to better understand how their designs have been put together. Examining the form, function, aesthetics, and sustainability of these designs will inform my design. Importantly, the selected precedents do not have the same primary function; another is office space and the other four are vertical farms, with and without other functions. The idea is, therefore, to pull information from all the types and compare, analyze and combine the information to assist in the creation of a well-planned and thought out design.
Case Study 1: Cloud Corridor

Form: Designed as a future residential concept for the city of Los Angeles, the above example shows a high-density, residential tower complex. LA boasts a skyline of residential, commercial and mixed-use buildings. MAD architects have designed a building that sits high within the site, alongside all the other residential high-rises going up in the city. MAD designed the complex of towers to encompass the ideals of MA Yansong’s Shanghai City. This philosophy combines the spiritual essence of people and nature in architecture.

Function: The structure holds six towers in total, spaced generously to allow for sun penetration, lighting, privacy and views for all living spaces. In this precedent, form relates directly to the function of the building. The concept behind the design was to take the horizontal sprawl of residential buildings with roads as corridors and integrate the same amount of sprawl vertically while using a similar road/corridor division.

Aesthetics: Sustainability is influenced by aesthetics. The green façade is a combination of glazing and vegetation.

Sustainability: As this precedent is not an existing building, the sustainable features are all proposed at this point. Some features are design-sustainable systems such as the vertical to horizontal sprawl. Space is laid out vertically, thereby saving horizontal space for regrowth of forestry or a park below the building area.
Name: Cloud Corridor
Location: Los Angeles
Architect: MAD Architects

Figure 28: Cloud Corridor Render
Case Study 2: Wyoming Vertical Farm

Form: The project is for an indoor farm in Jackson Wyoming, comprising a three-story 5,490m2 hydroponic facility. The basic form is a simple combination of steel and glass. The front facade has a mesh-like material. The three-story building has a long yet shallow floor plate, 45m x 9m, for light penetration.

Function: The building is intended to be an indoor growing facility. Crop production is estimated at 100,000 pounds of produce, consisting of leafy greens, herbs, and tomatoes. The idea of the facility is to take an un-utilized space and turn it into space which can help the community. The facility will employ citizens with disabilities and raise money for charities and the community. While primarily a growing facility, it will also play a big part in the community.

Aesthetics: Simple structural and simple aesthetics have been used here. The facade is mainly functional with glass and steel to allow for light penetration. A white mesh-like material used to highlight the entry. The building itself is in contrast with the neighboring building. The brown concrete structure of the neighboring building makes the white facade, glazing and steel structure very prominent.

Sustainability: Natural light, low powered LED lighting, photovoltaics, and cross ventilation are the main sustainable features of the building. The shape of the building “optimizes” the quality and potential for natural lighting. The hydroponic setup will follow a closed loop water nutrient cycle. All in all, the building will need to be sustainable as public funding will be covering the costs. Less cost means more going back to the community.
Name: Jackson Hole
Location: Jackson, Wyoming
Architect: E/Ye Design

Figure 31: Picture of final building
Case Study 3: Pasona Building, Japan

Form: A modern built concrete, steel and glass office building. The form is a standard square floor footprint. The building floor plates separate the office spaces from the growing areas yet still manage to incorporate the green design into the overall design.

Function: The building is a standard office building with the side function of growing plants within the building. The office spaces are designed both for office activities and to allow the workers to grow produce for their lunch or to take home. This is referred to as the farm-to-table office scheme. This particular building is reportedly the largest farm-to-table office scheme in Japan. The spaces have central growing areas. Both soil and hydroponic facilities are available for the use on many floors of the building.

Aesthetics: The facade shows a mixture of green and modern design features. The use of materials along with the growing wall makes the building stand out within the city area due to the contrast of the green with the concrete jungle.

Sustainability: Fresh vegetables, green walls, cross ventilation and glazing. Self-food harvesting is a very sustainable concept. Many urban developments in Japan are now incorporating this approach. This idea suggests a new way in which we see our day-to-day relationship with food in the workplace.
Name: Pasona
Location: Tokyo Japan
Architect: Kono Design

Figure 34: Pasona Facade
Form: This a standard shed-like warehouse plant factory. The existing building was previously an aeroplane hangar. The majority of the spaces is for growing. A large part of the floor plate has been opened up for planter setups. The building itself is 16m high, with a 4,780m² footage.

Function: The main function is to be a plant factory. The facility grows four diverse types of lettuce products and produces over 7.6 million heads of lettuce per year. The growth areas are segregated between hydroponic systems and aeroponic systems utilizing artificial lighting. The functionality of this design works so well that the company has set up many different factories around Japan.

Aesthetics: In my opinion, the look of this factory is unsatisfactory. It is primarily a steel shed-like structure with no windows and large open spaces within the building for growing lettuce.

Sustainability: There are a small number of efficiencies that contribute to sustainably. They re-use 90% of the water that goes into growing the plants. Photovoltaics add to the combined power usage of the factory. LED lights are used to provide the light needed to grow plants and thus less electricity is consumed.
Name: Spread Co. Ltd
Location: Shimogyo-Ku Kyoto Japan
Architect: Unknown

Figure 37: Internal growing systems
Case Study 5: Mashamba Vertical Farm

Form: The building is made up of arched sections. The sections can be put together to create large farms or small farm buildings. The kitset can be arranged as per the design according to the farmer’s preference.

Function: The goal of this building is to be able to cultivate land in any area in Africa. The building will comprise of fruit-bearing trees in the lower levels and smaller crop plants in the elevated levels. This building will also have spaces for living areas for the farmers. The building functions as a farm. As this building only takes up a small area of land, large areas remain in which larger trees can be planted.

Aesthetics: the structure itself is comprised of modular elements. Materials have yet to be decided, so therefore timber or steel could be used to build the modular structure. However, temperatures and common materials of the area dictate concrete as a possible choice.

Sustainability: Natural fertilizers, open cross ventilation, open light penetration and fresh water collection.
Name: Mashamba Vertical Farm
Location: Sub- Sahara Africa
Architect: Pawel Lipinski and Mateusz Frankowski

Figure 40: Mashamba Farm
Case Study 6: Aero Farms USA

Form: The design of the proposed building is, in my opinion, is basic. Additional spaces include growing spaces, germination chambers corporate offices and event space. However, the remodel will be minimal from the exterior. There is to be a 4,731m² extension added to the already large 1,676m² facility. The new extension is a modern steel and glass combination. Most of the physical change and re-model will be seen in the interior spaces to facilitate the growing of better products.

Function: Research facility and vertical farming warehouse. This facility will become the world's largest indoor farming facility. The 6,410 m² facility will host the production of over 2 million pounds of leafy greens every year. The functionality of the building will be mainly dictated by the systems installed. All such systems, including LED lighting for photosynthesis, hydroponic chambers and trays, water filtration and nutrient releasing machinery will be closely monitored by state of the art air and water monitoring systems to control quality and taste.

Aesthetics: The extension will be integrated into a complementary style and through the use of new materials on the facade. Glass and steel will be the main facade treatments to allow for natural lighting through the facility.

Sustainability: Many techniques such as closed-loop irrigation, stacked growing, and no pesticides will be used to contribute to the sustainability of the project.
Name: Aero Farms Head Quarters
Location: Newark, New Jersey the USA
Architect: KSS Architects

Figure 43: Aero Farms USA
4.5 Conclusion

All chosen Case studies have in some way informed the research and development of this project. Analysis of all six case studies has shown both successful and less successful aspects of the current model of Vertical Farming. Whereas current farming practice has mostly been on the outskirts of the city, we find that four of the six case studies that are only located within the Urban City fabric and have also been successful in these environments. The examples such as the Mashamba farm and the Wyoming Vertical farm are not placed in dense urban areas but moved away from the bulk of the population, however these work on separate merits. As the Mashamba farm is placed within a rural area it has the ability to extend and grow as per the need of the farmer, as this was the idea behind the overall design, to make something flexible enough to construct a movable farm.
Location in this project is a key, but so is a connection in relation to the physical and visual aspects of the design. Community interface and internal connection within the building are the main keys to why most of these buildings work well. As the current standard model is more closed to the public and is at best a factory type building. The Case studies chosen, have been a variation of both public designed and closed off type facilities. “Aero farms" and “Spread. Co” is a good example of having no public interface as they are at best factory facilities. Unfortunately, along with these types of facilities, the companies often develop a negative perception as the systems used are still relatively new. By having the public being a large part of the process we can make the systems and processes more common, with community integration helping achieve the overall idea.
5.1 Growth Mechanisms

This section lists the processes and methods that can be used in indoor vertical farming. These processes are currently the four most commonly used systems in indoor farming. From these systems, I will choose the systems I will use in my proposed building. They are effective methods that conserve water, easily movable, and encourage quick and healthy plant use.
• **Aeroponic systems:**
In the aeroponic growing process plants are grown using air and mist instead of soil and rain. Nutrients and water are mixed within the mist to quickly provide the plants with the medium they need to grow.

• **Hydroponic systems:**
This process grows plants using water as the main medium. The plant is suspended in a water / nutrient medium. The roots are within the medium, therefore, the plants are fed nutrients directly. This improves rates of growth, quality control and plants per harvest.
• **Drip Irrigation:**
Drip irrigation is a process whereby the plant is drip fed water and nutrients. This is also known as micro-irrigation and is a way of saving water. The water is dripped onto the roots or the plant so as the nutrients and water are absorbed more efficiently.

• **Aquaponics:**
This process involves growing plants with both water and fertilizer from living fish. The system works in a closed-loop typology. The droppings from the fish are transferred to the plants via the water piping, and the plant waste is then used to feed the fish and therefore causing them to re-fertilize the plants. This is used in conjunction with the hydroponic system.
5.2 Growth Types and Systems Used in Existing Farms

Listed below are the existing greenhouse or indoor farming modules. These systems are three of the most common and productive forms of stack growth. They produce 5–20 times more than traditional farming processes for the same area. I will be suggesting the use of these modular systems in my design.

- **A-Go-Gro System**
  This particular module consists of 22 to 26 tiers per module. It is 6m tall and produces 5 to 10 times more produce per area compared to traditional farming methods. It is used in Singapore indoor farming facilities, due to the high level of product yield. The 22 racks are incorporated onto an A-shaped structure. The module has a built-in water pulley system which creates flowing water to feed the plants. This is a hydroponic system. The energy required to power one A-frame structure is equivalent to powering a 60-Watt light bulb, according to Mr. Ng of "Sky Greens Vertical Farms" in Singapore.
Vertical Crop Conveyor:
Developed by the VeriCrop company, this module is a 3m high growing system that produces 20 times the yield of the traditional farming model for the same area. It is described as an “overhead plant tray conveying” system. The module has up to 30 plants per tray and up to 100 trays per module. Therefore, production is up to 3000 plants per yield. The VertiCrop system uses 8% of the water required for a traditional farm of the same size. Again, this is a hydroponic system.
ZipGrow Towers:
This module is a 3m high, 4-sided system (4 long tubes side by side). It holds up to 8 large plants per tube and up to 10 smaller plants per tube. Standard tubes are a simple PVC hollow pipe for seedlings. The tubes house the growing medium consisting of PET (recycled polyethylene terephthalate) which hold the plants in place. The ZipGrow system can be used as both an aquaponic or hydroponic system. This system can grow up to 3 times more than the traditional method for the same area.
Figure 52: System typology in relation to money
5.3 Standard/ Universal Building Setup

The following are common systems used in existing indoor farming systems. These are the standard factory indoor farms, and the systems incorporated in a high-performance building. I will be proposing high-performance systems for my building.

High-Performance Building Systems

• Heating, Cooling, and Ventilation:
In a high-performance building, the idea is to reduce the carbon footprint produced by the building. One way of lowering the energy consumption for a lower impact on the environment is a combined heating, ventilation and air conditioning unit (HVAC). This type of system also makes it easier to control the air conditions in the growing rooms by constantly cleaning the air to reduce contamination or airborne diseases.

• Double Facade:
These types of facades or building skins comprise two glazed layers with a cavity between them in which the air can circulate, allowing natural or mechanic ventilation. This effect is called the stacking effect and occurs when warm air rises above the cold air within the space of the facade. This effect can ventilate the building without the need for energy consumption. It will also create a better overall environment.
- Irrigation and Water Harvesting:
  This system relies on a recycling system. The water used for the plant growth is either absorbed by the plants or re-cycled and filtered to be used again for the next generation of plants. Accordingly, the irrigation process is based on the recycled water with the rainwater harvest tanks adding to the water absorbed by the plants. Water and nutrients are pumped through the supply pipes that feed the plants. It then makes its way to a 3-chamber filtration system. Rain harvest systems for such a building design with these proportions will require 3–10 large tanks, depending on the amount of water needed to supply the plant production. Rainwater harvesting systems are made up of a catchment surface, conveyance system, storage, and treatment. The roof surface area collects the rainwater which is then funneled into a coarse filtration tank and moved later to the storage tanks. It is then pumped, further filtrated and then again treated. Before it reaches the plants, nutrients are pumped into the pipes for supply to the plants. The nutrients differ depending on the plant types being produced.
• Solar and Renewable Energy:
Providing alternative sources for energy plays a big part in a high-performance building. These alternative energies are also known as a “renewable energy” because we do not expend energy to collect more energy. Solar panels are a notable example of such high-performance systems. Photovoltaic panels harvest the sun’s energy. The energy is then stored in a large battery. When the electrical energy is later required it is then dispersed to the areas it is needed. The roof of my proposed design will need to have sufficient roof area to provide a substantial amount of energy to power the LED lighting for the plants.

• Lighting
The lighting used within the high-performance building structures is LED (lighting emitting diodes). These lights are low energy consumers. It has been established that plants only require red light and blue light, therefore as LED light contains it is perfect for plant growth. The need for only two light spectra makes these LED lights particularly very low in terms of energy use. As well as the LED lighting, the building design will require a large amount of daylight. Daylight penetration into a building is 1.5 times the size of the window area. Therefore, if the floor to floor height is 4m and the window is floor to ceiling, the daylight will penetrate 6m into the internal space of the building. The proposed floor area to daylight area of penetration surface should, therefore, be designed in such a way that daylight is the main source of light for the building. This should drastically reduce the energy requirements.
• Economic:
There are two areas of economic estimation are important to take into consideration for this project. Firstly, the estimated cost of the build and development of the building, including materials, technology, structure, and labor. Ideally, it would be good to have a lower initial cost. Secondly, there are the running costs in comparison to the profits from the function of the building. Ideally, the profits should largely out-weigh the running costs. The production of plants will bring in profit to cover both the build and the running costs. Due to the energy efficient design, there should be tremendous savings over a 25-year period.

• Social Impact:
Designing a “first of its kind” vertical farming building in Auckland City will have a big social impact. Firstly, I will be proposing a sustainable, green, healthy public environment for the surrounding community to access. Secondly, I believe that this project will help to better educate people on fresh, healthy and in-house grown foods, not to mention the low costs associated with growing food on-site. This intended design has many potential benefits for Auckland City. As well as the advantages mentioned above, I also see that this building could change the way we think about where our food comes from. It should provide an education for the general public and for those who work at the facility.
5.4 Why Vertical Farming

- **Constructibility:**
  Site location is important to the project, as we have the opportunity to enhance the viability of the design incorporation. The chosen site itself is located in the center of the city at the junction of Albert and Wolfe streets. The current building is dilapidated, with only the basement and ground floor being used as a Wilson’s car parking facility. Taking such a previously used building, stripping it back and using the existing structure (with additional reinforcements where necessary) may make the building process more efficient and sustainable.

- **Environmental and Sustainability:**
  This design tries to take into consideration any sustainable features that could make the building more efficient in terms of use of resources. Minimizing the complexity of construction by re-using whatever can be used of the existing structure is an important first step. The proposed new building includes features such as LED lighting, an HVAC system, photovoltaics, rainwater collection tanks and double facades. The goal of this project is to help educate people for and support efficiencies while keeping running costs down.
• Conclusion
Integration of agriculture within modern architecture is becoming a common trend. The incorporation of agriculture in high-rise buildings is a way of making these buildings more sustainable. Increasing the amount of green growth within the building improves air quality by cleaning the air within and around the building. Looking at the positive and negative features of the integration of architecture and agriculture confirms to me that the next step in our farming evolution is more positive than negative. With regard to the negative aspects of vertical farming, solutions can be developed to allow for the more sustainable production of electrical energy, and to create tastier plants and address pollen allergies.
• Summary of Chosen Systems

Vertical farming is the way of the future. Apart from a few aspects surrounding resource issues, there are many positives. The systems used in vertical farming are simpler and have less of an impact on the environment than do current processes for traditional land-based farming. If vertical farming becomes more the norm we can hopefully re-design and develop solutions for all the kinds of issues surrounding taste, resources, and availability within the urban environment.
Figure 53: Growing Tower
6.1 Site Selection Criteria

The site selected for the vertical farm must incorporate a number of factors and considerations. The location within a built-up and dense urban environment, with a large population, is crucial to the viability of the project. Accessibility to surrounding restaurants, supermarkets and produce distributors is important in relation to food miles and to ensuring fresh, healthy produce. As an integral part of the production of fruit and vegetables, ingress of sun and light to the site make orientation a vital consideration in determining site location.
Figure 54: Site Location Maps
6.2 The Chosen Site

The selected site is located in Auckland’s central business district (CBD). At the present point in time, it is a derelict, leaky building situated on the corner of Federal Street and Wolfe Street. The basement and ground floor is currently used as a Wilson’s car park. The site itself consists of two buildings, the “Yates Building” and the “Yates Storage Building”. In 2012 the Yates building was denied Status A Heritage protection, even though the building itself is over 100 years old. However, the main building on Albert Street was awarded Status B protection, while the other two buildings were not given any protection under the regulations. The upkeep costs associated with maintaining a heritage building became unaffordable for the owners and maintenance has currently lapsed, leaving the current buildings in a very poor state.
Figure 59: Section to show land movement
History of the Yates Building:
The Yates Building was constructed in 1911 and was one of the first buildings to use a steel-reinforced concrete structure. The purpose of the building was as a production site, including storage and offices, for a seed company. The building’s site was seen as an awkward and irregular shape which caused design issues. Vertical circulation is limited within the building with two elevators located in the center of the building and stairs at the rear. Later additions and an increase in floor area were carried out in 1928 and 1948, increasing the floor print to 7600m².

Existing notable buildings in the area:
Currently, the location boasts a wide variety of building typologies with a variety of uses. There is also a wide range of heights through the surrounding buildings. Quay West Apartments and the West Plaza are possibly the two most iconic buildings in the area. Quay West Apartments comprises 20 floors and is 117 meters tall. West Plaza is 74 metres tall with 18 floors. Directly opposite the site is the Tower Insurance building, which is 13 floors high.
6.3 Current Condition

The Yates Building has been abandoned for over 10 years now. In 2011, the government cleaned up the graffiti on the building as part of preparations for hosting the Rugby World Cup. In 2012 the Yates building was granted Heritage Category B which offers some protection. In 2002, according to the property file (Auckland City Council), the Yates building was subdivided from the Wolfe Street building. As a result, the heritage classification only applies to the Yates Building, and not to number 9 Wolfe Street.

- Heritage Status Category B:
  Heritage status under Schedule 14.1 of the Historical Heritage Schedule implies that the site/building is significant to the local geographical area, giving it a historical importance. Rules surrounding Category B heritage are as follows:
  1. Regarding demolition: demolition work on Category B buildings is not recommended where it will result in adverse effects. Adverse effects mean changing the building in such a way that the Heritage Status could change, due to it losing its significance to the geographic area. However, resource consent for demolition may be acquired if the building is in bad condition.
  2. Avoid any permanent relocations. However, the significance of the building to the public is more important than retaining the present location.
  3. Infrastructure: maintenance, repairs, and upgrades are to be carried out in a manner that does not affect the heritage status of the building.
Figure 61: Site Analysis Maps
Summary:
The chosen building is at 9 Wolfe Street, Lots 1 and 2 – as per the council plans attached. The Yates Building will remain as is and will not be a part of my project. Due to the many current issues with the building, such as the weathered appearance and it’s weak structural integrate, I am suggesting to demolish the existing building and start anew.
6.4 Site Analysis

Site analysis

- **Access:**
  Public transport in the area is excellent, with major bus stops and the Britomart train station within walking distance of this site. Queen Street, Fanshawe Street, Hobson Street, Albert Street and Customs Street West are large multi-lane streets creating easy vehicle access to the site.

- **Size:**
  The building has a 200m² footprint and a total of six stories.

- **Orientation and Climate:**
  The site is in downtown Auckland City. The average temperatures in the city range from 11 degrees Celsius in winter to 20 degrees Celsius in summer. Annual sunshine hours are 2,060 hours, with an average rainfall of 1,240mm per year. The prevailing wind direction is from the South-West.
Figure 62: Sun Shadow Study on Site
6.5 Site Context
7.0 Design Response

7.1 Objectives of Overall Design

The overall aim of this project is to design a well thought out, mixed-use high-rise building with the primary use as a vertical farming. The building will be integrated into the Auckland urban environment with the intention of benefiting both the community and to educate people by raising awareness about the food we grow. The outcomes will be an alternative solution that reflects new modern development in farming, and an approach that encourages the general population to eat more local, healthy foods.
Figure 67: Design Program
Building Zones and Breakdown:
The building design intends to connect and harmonize three zones. The zones will be set up to aid the overall function of the building.

1. Public Zone – this area consists of cafe’s, viewing areas, restaurants and an information center.
2. Educational Zone – this area is made up of research labs, training facilities, and a plant awareness lecture room.
3. Growing Zones – consists of large spaces for open growing, as well as areas for seed storage, seedlings, produce storage, transportation, and office and management areas. One zone needs to seamlessly lead into the next. Function and form need to be clearly communicated to users to enable movement through these zones without any misunderstandings.

Figure 68: Building Zone Colours
7.2 Horizontal to Vertical

The current farming model mainly occurs around a horizontal plane. Plants are commonly grown on the ground, with some nutrient base, over a sprawled area. This form of land use is unsustainable as land is increasingly becoming a scarce commodity. If we can wisely utilize our available land in such a way as to maximize our farming potential, this creates a solution to these issues associated with food production, sustainability of resources and creating a vertical stack should not only create a different type of farming but should also increase the overall area in which to grow. By taking a 10m2 area and building upwards another five stories, you now have 50m2 in which you can successfully plant and grow crops. By doing this, we can dramatically change the amount of workable land area in which to grow. And as demand for food increases, we can build upwards to increase productivity and production to suit demand.
7.3 Circulation and Connection

A vertical farming system dramatically changes the current food farming model from a sprawled to a stacked system. This can give rise to diverse ways in which we can deal with connections within the building. Connections between zones and visual connections are therefore important to maintain through the design process.

Circulation within the building needs to be free flowing, as physical connections need to work within the visual connections to produce an overall positive atmosphere within the spaces. For example, movement from the restaurants to the viewing areas will need to have a circulation overlap; being able to view the food you are eating is an important part of educating the public and encouraging healthier eating.

Visual connection within the space is very important as it allows each space within the building to communicate the intended design to the users and keeps the overall openness of the building. Views are established from all floors and towers allowing the entire building to be viewable. The atrium space allows for clear views from more than one point.
7.4 Form and Shape

The final building form has been determined by various typologies and the shapes of surrounding buildings. Surrounding buildings, movement through the site and flow of overall connections. For the building to fit into the existing context it is intended to pull shapes and forms from the existing surrounding context. The flow and overall movement within the buildings need to work on a larger scale as well, suggesting the curves.

The final overall shape and formwork with the three ideals chosen to connect the building to the site. The form draws its main shape from the surrounding curved buildings. These buildings stand out due to their curvature. The access to the site has mapped out the shape of the atrium areas also allowing entrance into these areas, making them more defined. It is suggested that the final shape works well connecting the proposed project to the current site.
Figure 75: Site Access Exploration

Figure 76: Final Form
7.5 Massing of Typologies

Massing is broken up into five main categories. Each category is massed according to the amount of activity taking place at each location.

1. Growing areas: these areas are expected to make up the bulk of the building. In order to make the building and running costs viable, the facility needs to produce enough product to sustain the demand. Therefore, the growing area needs to be large enough to meet this need.

2. Storage: along with growing spaces, we will need storage areas, whether that be for seedlings, seeds or harvested yield until it is collected or dispatched. This size of this area needs to be consistent with the amount of food being held, so the size of the harvest will determine the size of the resultant massed area.

3. Public areas: the public areas are what will attract people to use the building. Public interaction is key to making the building a success. The public areas will include the restaurants, cafes, viewing areas and plant-based interaction areas. Fresh plant based product will be available at all locations to allow the public to connect with the basic premise of the building.
Figure 77: Photographs of massing exploration
4. Education: these areas will mainly be for training and research. The sizes of these areas will be determined by a number of people wanting to further their professional plant-based knowledge and also dependent on how many workers are needed within the facility. The research areas are to be a suitable place for New Zealand professionals to make their mark in the field of plant-based science and may also help with testing in ways that most plant-based research facilities cannot do.

5. Car park: A lower car park area already exists. However, if we provide more parking within the building we can bring in more of the public. As underground parking areas are filled with exhaust fumes and are naturally dark places, the recycled air filtration system and overall massing should make this space different. The massing for this area will remain a constant through the design process.
7.6 Zoning and Order

With regard to the different zones, I have explored many ways in which to order them (as previously mentioned in 6.4). As there is more than one type of area in this high-rise building, arrange the design areas in order of both importance and size. The spaces within the building have also been ordered in relation to connection and movement. The diagrams below show an exploration of these spaces within a high-rise situation.
7.7 Towers and Atrium

Light and open space are imperative to the design of this building. The plants need as much light as possible to enter all areas of the building, as this cuts down the amount of LED lighting needed to supplement the growth of the produce. The open space will add a visual aspect to the building to prevent it from looking like a utilitarian factory farm. To incorporate both these aspects into the design, I suggest an atrium. The atrium space will allow light to enter the central part of the building and also create an opportunity to arrange spaces within the building that visually connect the atrium. Alongside this, the atrium also creates a more interesting and sociable environment by attracting people to the open spaces.
Figure 80: Shadow Cast by West Plaza

Figure 81: Sun entry to Atrium

Figure 82: Atrium in blue
7.8 Community Interface

Along with providing jobs for the public and surrounding community, this design project intends to also provide education to the community. By creating harmonious interfaces between the public areas and the growing areas we can hopefully connect the public to the building in a new way, and get the public interested in a new farming method.
7.9 Social and Recreational

As this building is mainly used for farming, there needs to be a strong social connection in order for it to become integrated into the urban environment. The public interface is one of the three main zones incorporated in the building, with the others being the education zone and the growing zones (as mentioned in 6.1). I have considered two variations on connection, firstly by connecting the public using a visual cue, and secondly by physically engaging the public with the other two zones. To successfully bring the public into this building, it has been decided to use both the visual and physical connections. The users of the building will range from people on their lunch breaks and after some fresh food, to children on a school trip to learn more about farming. The building will be open to all public as it creates a green oasis in an area where there are no parks in close proximity.
Figure 83 b: Social and Recreational Zones
7.10 Transport and Efficiency

The main idea for the locating this building in the city is to reduce food miles and transport costs. Farm produce generally goes through a number of hands before it gets to our plates. To make the product cheaper, and fresher, we need to limit this multiple handling. By facilitating access for local supermarkets, restaurants, cafes, and sales to the general public, we can dramatically reduce the amount of transport required. By looking at the site and access in and around the site. Location of drop-off points and pickup of the product are important; these areas will need to have easy access to allow overall smooth collection of the plant produce.
Figure 84: Car Park Plan
8.1 Development of Areas

The massing development outcome has been based mainly on the connection between each of the previously discussed three zones. The overall mass uses the ideas explored in 6.3 and 6.4. This shape works well in the site and relates to the surrounding buildings as well.

Program schedule:
This building will contain the following areas contained in the building:
- Public Area
- Growing Areas
- Information center
- Offices
- Storage
- Transport Area (pickups and drop-offs)
- Viewing docks
- Education and Research areas
Figure 85: Program Schedule breakup
Growing Areas

Growing zones will have three types of growing areas:
1. Dense growing zones, in which the chosen “zipgrow”, “ago-gro” and “verticrop” systems will be used to generate the bulk of the product.
2. Vertical growing walls. Unfortunately, it is not affordable to grow all the plants on large vertical systems as the space lost in constructing a harvesting system would not be efficient. Therefore, the proposed is that the atrium and external façade of the building be lined in some areas, with an eatable green wall system. This also allows a visual connection to the public as they can view the growing process from anywhere in, and around the building.
3. Small scattered growing areas. Areas such as the café’s, restaurant, reception and produce store will display smaller systems to link the growing areas and overlap all areas with the main growing zone.
Figure 86: Growing Areas
Storage Areas

Figure 87: Storage Areas
Public Areas

Figure 88: Cafe Area (Public)
Training and Research Areas

Figure 89: Training and Research Areas
Green Areas

The growing areas are composed of green vertical growing areas and open green zones. As proposed previously, the green walls will line parts of the interior atrium space whereby the plants such as common herbs and lettuce grow well. Not all the spaces can grow vertically efficiently.
Atrium

Figure 91: Growing Atrium View
8.2 Structure and Materials

Figure 92: Grid Structure for Columns

Figure 93: Posts and floor plates

Figure 94: Section of Structure
8.3 Circulation

Figure 95a: Building Circulation Plan

Figure 95 b: Building Circulation 3D
8.4 Floor Layout

Figure 96: Building Floor Layout
8.5 Sustainability and Facade

Figure 97: Solar Glass Wall

Figure 98: Solar glass Panel

- Low Iron Glass
- PVB
- Photovoltaic cells
- PVB
- Float Glass / Ceramic
Figure 99: Green Walls

Figure 100: Vertical farming
Figure 100: Vertical farming
Further plan development has lead to a different plan shape or layout. The different layout uses the surrounding available space more efficiently than the previous floor plate designs. The plan is however still derived from the surrounding buildings curvature to allow for better transition into the site. The paths and movement or flow of the building are still derived from the connections of large populated areas.
About the building

Proposed and Intended:
Within the completed design outcome, there are some areas that are unclearly identified. These areas cannot be shown properly within the design but may be embedded in the building later. These areas of the design are the “intended areas”. For this design, the intended areas are mostly the parts of the design such as:

- Intended to keep the original lower carpark, however, redesign the layout. However, this may not structurally work within the final design.
- Intended for several different plant species to grow among the open viewing areas, however, these rooms may soon become more contained in order to better control the air and temperature of the growing areas.
- Intended growing systems. The 3 types of growers being used to grow plants such as the zip-grow, the Vertical Crop Conveyor, and the A-go-gro system. These systems may be different depending on the amounts of product needing to be produced. The already researched and discussed systems such as Air cleansing systems, lighting, and water systems are all proposed systems and if the design is not built with these elements within it, the design could fail.
Figure 102: Structural elements
Aspects of the overall Design

The common design aspects that make up the building are as follows:

1. Sustainable - the sustainable features such as green walls, green roofs, natural lighting, natural ventilation and rainwater collection, help add to the buildings overall outcome. The green-walls help define spaces and add a verticality to the internal atrium space. The rainwater collection adds to the main plant water supply. The natural lighting feeds back into the public network. The photovoltaic glass also provides the plants with harvested natural energy. And lastly, large openings in the building encourage natural ventilation.

2. Public - Access to the public is very important to this design as the idea is to increase and help educate the public on vertical farming. However, most growth spaces need strict monitoring in order to grow well. This can be solved by higher quality air control systems and the particular choice of plants. Plants such as lettuce or leafy greens will require less control whereas tomatoes will require more.

3. Structure – (Primarily the external structure.) This has played a big role in the outcome of the final design. Large steel beams and cross exposed large cross bracing makeup the facade of the building. This is also to aid in the current earthquake proofing and structural reinforcement of current Auckland buildings.
Technical Schematics: Section Showing Water Supply

Twin pump system to pump water back up through building

Nutrient supply stations

Collection tank

Clean water supply

Roof stormwater collection

Filtration Tank

Air Filtration system into Air supply unit

Clean water

Grey water

Nutrients water

Figure 103: Water Supply Schematic
Technical Schematics: Section Showing Air Supply

Figure 104: Air supply Schematic
Final Outcome

Figure 105: Federal Street Perspective
Figure 106: Albert Street Perspective
Figure 107: Wolfe Street Perspective
Figure 108: Sectional Perspective
Figure 109: Plans
Figure 109: Plans
Figure 110: Structural Axonometric
Figure 111: Internal Market Space
Figure 112: Internal Cafe Space
Figure 113: Internal Growth Space
Benifits of the Building.

A large reason behind the design is to benefit the Auckland public by educating them about the food we eat. The public aspect of this project is what could make or break the outcome. The benefits to public health and influence on people to help them make a better choice when it comes to food. The location of the building is in the centre of the business hub, an area where most people are too busy to make good choices on the food they eat. By giving the public a place to come, not only for food but as a public area where they can take a break, gives more opportunity for the design to succeed. The final design possesses an intended relationship between the human aspect and the fresh food.
As the population grows the global demand and pressure increases to produce food for billions of people. With limited resources, infrastructure and land it becomes crucial that we improve current food production systems. Changing environmental factors put pressure on the current means of production of fresh produce. The way in which fresh produce was and is grown is changing. Global warming has increased temperatures and made it harder to control growing conditions outdoors. The implementation of indoor growing houses is becoming more common due to the environmental controls. Along with environmental control, sustainability and pollution can be managed and reduced through the implementation of mechanical systems within an indoor environment.
The project investigated the use of indoor farming systems within a built-up city context. The design response is a vertical mixed-use building located on the corner of Federal Street and Wolfe Street in Auckland's CBD. Through analysis and research of new farming models, the design has implemented public, educational and growing aspects of the vertical design. The site location has been determined through a strong need for connectivity and access, as all vertical models show these to be the driving factors. The design responds to a need for key connections both externally with the wider community, and internally within the building. By integrating connection both physically and visually, between the community and building, the project has effectively involved the city community within the building. The negative perceptions of the public about vertical farming will be challenged as all vertical processes are put on display. Taking into consideration the lack of efficiency, excess use on un-renewable resources and weather unpredictability of outdoor farming, indoor farming seems to be the way of the future. The practice is currently evolving and changing to correct any current issues, with this project being part of the exploration of the subject. Instead of the remaining in the past, this design successfully shows an ongoing Urban farm with an educational and social aspect.


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