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Planning for building-integrated agriculture in Las Vegas

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PLANNING FOR BUILDING INTEGRATED AGRICULTURE
IN LAS VEGAS

by

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Bachelor of Arts in Architecture
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2005

A thesis submitted in partial fulfillment of
the requirements for the

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College of Fine Arts**

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ABSTRACT

Planning for Building Integrated Agriculture in Las Vegas

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High food prices, concern about food nutrition and safety, and an awareness of commercial farming's environmental impact have generated a renewed interest in sustainable urban agriculture. Advances in controlled environment agriculture (CEA) have made it possible to grow food virtually anywhere in a much more sustainable manner than traditional field-based agriculture. Locating and planning urban farms using retrofitted existing building stock to maximize food production and ease of distribution in Las Vegas requires consideration of multiple barriers related to geography, economics, and the built environment. Consideration of these factors in the planning process informs the design of a successful BIA facility. The site selection process for urban agriculture projects is critical to the project's long term sustainability, while the site's adaptation requirements directly influence start-up costs. Detailed analysis of the factors in these stages can therefore yield valuable initial viability and feasibility information. This thesis presents a planning strategy specifically for selecting an appropriate site and designing for building-integrated agriculture (BIA). First, a list of critical factors for a successful urban agriculture project is developed from the material discussed in the literature review and case studies. Next, a detailed site selection and analysis process is developed to provide insight into the adaptations needed to turn an underutilized building into a functional urban farm using new BIA technologies. The strategy is then applied to a chosen site in Las Vegas.

The developed planning process can be used as an assessment framework by potential investors, developers, entrepreneurial urban farmers, and others for planning and implementing a productive Las Vegas urban farm using existing building stock. The architect can use the developed strategy to inform the planning design phase and ensure a well-integrated and feasible project.

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ACRONYM GLOSSARY

- AIA.** American Institute of Architects
- AIVC.** Air Infiltration and Ventilation Centre
- ACGA.** The American Community Gardening Association
- BIA.** Building-Integrated Agriculture
- B-ISA.** Building-Integrated Sustainable Agriculture
- CEA.** Controlled Environment Agriculture
- CEAC.** Controlled Environment Agriculture Center (of the University of Arizona)
- CMU.** Concrete Masonry Unit
- CPUL.** Continuously Productive Urban Landscape
- FAO.** Food and Agriculture Organization (of the United Nations)
- GIS.** Geographic Information Systems
- HDVGS.** High Density Vertical Growing System
- LVVWD.** Las Vegas Valley Water District
- NTS.** Not to Scale
- OTA.** Organic Trade Association
- PALENC.** Passive and Low Energy Cooling
- PCL.** Plant Cable Lift
- UA.** Urban Agriculture
- UN.** United Nations
- VIG.** Vertically Integrated Greenhouse

CHAPTER 1

INTRODUCTION

Current Issues Facing Agriculture

The number one priority of the United Nation's (UN) Millennium Development Goals is "Eradicating Extreme Poverty and Hunger" (United Nations web). It has been suggested that this, as well as three additional Millennium Development Goals, is directly or indirectly related to issues caused by the current agriculture system. The additional goals affected by agriculture are: reduce child mortality, improve maternal health, and ensure environmental sustainability (Mougeot, *Growing Better Cities* 13). Adding to the current challenges, recent food prices are increasing at all-time rates; in February 2011 food prices increased 3.9% according to the Associated Press (AP 3). Data shows that in 2008, high food prices forced 115 million more people into hunger and preliminary evidence suggests that up to 105 million people could become poor due to rising food prices alone (World Bank 4). The high prices were mainly caused by oil and biofuel demands on current agriculture resources (World Bank 2). This pattern will continue as long as current agriculture methods are widely used because of economic benefits to producers such as the petroleum industry from the link between food and energy markets (Mensbrughe et al. 4).

Achieving the UN's goals becomes even more complex when one considers that food demands are growing; according to the United Nations' *World Population to 2300* report, by 2050 world population could reach between 8.9 and 10.6 billion (3). It has been suggested that if current resource-intensive farming techniques continue, an additional land area the size of Brazil will be needed to feed these people. This amount of new arable land is not available (Despommier web). In addition to land needs, the world's thirst for fresh

water will continue to grow. Currently, world agriculture uses nearly two-thirds of freshwater extraction and is usually seen as the major cause for global water scarcity (Bruinsma 19).

Projections also show that this growing world population will largely be an urban population; over half of the world's population -- 4.5 billion people -- will live in cities by 2020 (World Bank web). This makes for a growing health problem because of the current separation between the urban population and its food source. University of California Los Angeles' (UCLA) Center for Health Policy found that the highest percentage of people affected by obesity and diabetes live in neighborhoods that have many fast-food restaurants and little access to grocery stores and fresh food (Babey et al. 1). These neighborhoods are also called food deserts¹. Food deserts are commonly found in underserved urban neighborhoods and especially in communities of color (Babey et al. 1).

The growing health problem due to limited healthy food access is also of economic concern because of medical costs. Diabetics incur an average expenditure of \$11,744 per year (Dall et al. 596). A healthy, local, and affordable food source for the urban population can act as a preventative health care strategy to help reduce the financial burdens of those that are the most food insecure². Kaufman and Bailkey cite a Rutgers University study by Hamm et al. on the impact of community gardens in Trenton, New Jersey, which found that under certain conditions, increased vegetable consumption of vegetables grown in

¹ Food deserts are a major source of health problems. The Mari Gallagher Research and Consulting Group defines food deserts as "large geographic areas with no or distant grocery stores. Often they also have an imbalance of food choice, meaning more nearby fringe food such as fast food, convenience stores, or liquor stores" (Gallagher 1).

² This is supported by a study showing the relationship between obesity and healthcare expenses from a 1995 article. Nutrition education and healthy food was part of the weight reduction program in the study which showed that after one year patient diabetic and hypertension prescription costs were reduced by 50 percent (Collins and Anderson 373).

Trenton's community gardens would save approximately \$500,000 per year in cancer treatment costs (71).

The environmental, human rights, and health issues resulting from the current agriculture dilemma show the need for advancement in world food security towards a more sustainable agriculture, especially to satisfy urban food needs. In the current system, it seems urban dependence on resource-intensive food will continue to grow with the urban population if healthy food is not made widely available at a local level.

Designers, in particular, have a social commitment to using their unique skills to help develop sustainable urban agriculture (UA) because they are inherently concerned with the urban landscape and "have contributed indirectly to the pestilent slums in which much of the world's population now lives by failing to bring our skills to a vast, unserved sector of human society" (Fisher B6). Investigating how to best integrate new technologies for local food production in cities is a way design can contribute to a better understanding of how to create urban spaces that support a healthy population.

Sustainable Urban Agriculture – A Potential Solution

Sustainable agriculture is a goal that addresses current agriculture problems. As described in the 1990 Farm Bill law:

the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations; and

-enhance the quality of life for farmers and society as a whole (Gold 1).

These sustainable values can be applied to the urban landscape to help further define the goals of sustainable *urban agriculture* (UA). A comprehensive definition of UA is:

UA is an industry located within (intraurban) or on the fringe (periurban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area (Mougeot, *Urban Agriculture* 10).

This description of UA is an adaptation of Smit et al.'s definition and is widely used by UA scholars³ because it includes an emphasis on the integration of UA into the surrounding urban system. It is helpful in setting parameters for this study which is concerned with sustainable agriculture practices in the urban landscape, or simply, UA.

There is evidence of growing support for UA and awareness that "UA is an integral part in [sic] a continuously productive urban landscape (CPUL)" (Michaels 218). Awareness of UA has manifested in multiple ways. "Locavore" was the Merriam Webster 2008 word of the year⁴. Movies such as "Fast Food Nation" and "Food Inc." have attacked the corporate agriculture structure and been commercially successful. Vertical farming visionary Dr. Dickson Despommier continues to gain media exposure for promoting urban buildings that are designed for food production and distribution. The Vertical Farming Project website is regularly updated with architects' new visions of vertical farms. The USDA recently launched the "Know Your Farmer, Know Your Food" campaign to increase the public's awareness of where its food comes from and reinforce the idea of

³ See Colasanti 6 and Veenhuizen 11.

⁴ Merriam Webster defines a locavore as one who eats foods grown locally whenever possible.

buying locally grown food. Disneyworld has even dedicated a theme ride to an exhibit showcasing sustainable agriculture technology which has proven to be a highly successful agritainment enterprise. Even more recently, a restaurant in Saudi Arabia designed by Thomas Klein International included an internal farm.

Local government agencies have also taken notice of the potential of UA because the lack of access to healthy food is being seen as a public health issue. For example, as a response to findings from poor health and low-income neighborhood correlation studies, Baltimore established one of the first food policy coalitions. A series of meetings involving the Baltimore City Health Department, the Department of Planning, and the Johns Hopkins University's Bloomberg School of Public Health led to the formation of the Baltimore Food Policy Task Force, which is now jointly led by the city planning and health departments (Hodgson 10). The Baltimore City Planning Commission has further integrated good food into their policies by adopting the Baltimore Sustainability Plan which states the need for a food system that supports public health (Hodgson 10).

The growing interest in healthy food also has economic incentives. The Organic Trade Association (OTA) states that, "with annual growth of total U.S. food sales in the 2-4 percent range since 1997 and organic food growth in the 15 to 21 percent range, it is clear that organic foods are making continuous progress into the American mainstream, adding more than \$10 billion in annual sales since 1997" (OTA, 2006 1). The OTA reported that in 2009 organic consumer product sales in the US grew 5.3% to reach a total of \$26.6 billion (OTA, 2010 1)⁵. While growth in 2009 was less than the 15 to 21%

⁵ Despite the exclusion of hydroponically-grown crops from organic certification, this thesis makes the case that high-quality hydroponic crop producers are competing for the same healthy food consumer market as the organic food industry. These two industries, organic food and hydroponic food, both qualify as

predicted by the OTA in their 2008 report, the organic fruits and vegetables category grew 11% and accounted for \$9.5 billion in sales which is 38% of the total organic food market (OTA, 2010 1).

UA and local food markets, however, only capture tens of millions of dollars of this billion dollar healthy food market (Mougeot, *Urban Agriculture* 2). UA has not generally been considered a large money-generating commercial farming venture in the United States; its role has been complimentary to larger food suppliers (Mougeot, *Urban Agriculture* 2). Historically, but with exceptions⁶, UA has been associated with community gardening and other forms of agriculture that are meant to subsidize local food needs. This approach is quickly changing to a profit-driven model, however, due in part to a more visible connection between clean energy, water, and agriculture⁷ (Woody F5). Traditional agriculture's contributions to climate change and inefficient use of natural resources have created markets for technological innovations that reduce those effects (Woody F5). Some of these technologies are for the UA market.

The new technologies that are being developed to tap into this UA market have historical precedents; Jane Jacobs observed that since society began, innovations in agriculture have depended on technology perfected in urban settings. Entrepreneurs have increasingly taken notice and begun their search for “the next new thing in an old business: agriculture” in urban areas (Woody F5). One of the promising agricultural technologies

sustainable agriculture by providing healthy food using environmentally-responsible production (Brooke 59).

⁶ There are “a few highly successful market gardens have been in operation for a number of years” (ACGA). Also, there are some economically viable non-profit and for-profit urban farms such as Greensgrow in Philadelphia and Growing Power in Milwaukee but again, these are currently the minority and not the majority.

⁷ The event, “Agriculture 2.0” can be seen as evidence of entrepreneur interest in sustainable farming technologies. This is a new event most recently held in the spring of 2010 in Silicon Valley, California for the purpose of partnering entrepreneurs and investors with sustainable farming technology companies.

currently being perfected in the urban setting is highly efficient, flexible, and more affordable turnkey CEA systems designed for BIA applications.

Caplow and Nelkin introduced the idea of BIA in 2007 at the 2nd PALENC⁸ Conference and 28th AIVC⁹ Conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, in Crete Island, Greece (Caplow and Nelkin 172). Their research proposed rooftop greenhouses' thermal benefits. Since this conference, Caplow has fine-tuned a definition for BIA which appeared in "Urban Futures 2030":

Building Integrated Agriculture is a new approach to production based on the idea of locating high-performance hydroponic farming systems on and in buildings that use renewable, local sources of energy and water (Caplow 55).

Keith Aggoada, founder of Sky Vegetables, defines BIA as "...productive and profitable building-integrated sustainable agricultural systems, which can be widely implemented on existing and new buildings in cities and towns around the world" (Keenan 2)¹⁰.

For the purposes of this study, BIA will be defined as a type of UA in which an existing building has been retrofitted with an integrated turnkey CEA system for the purpose of high-intensity urban food production and distribution.

⁸ See Acronym Glossary, p. ix.

⁹ See Acronym Glossary, p. ix.

¹⁰ It should be noted that Keith Aggoada describes BIA as Building-Integrated Sustainable Agriculture, whereas the definition provided by this thesis excludes the term sustainable. While BIA is less resource intensive than traditional field agriculture, it still depletes resources and therefore can not be considered fully sustainable.

Potential for Agriculture in Las Vegas

The City of Las Vegas, Nevada, is a prime example of an urban area that should be concerned with providing food security for its population. The term “food desert” applies to Las Vegas in two critical ways: first, several neighborhoods in Las Vegas fit the MG definition of food deserts because of the overwhelming presence of fringe food and lack of easy access to grocery stores. Las Vegas does not have a local food source because it is located in an ecological desert currently in the worst drought on record according to the Las Vegas Valley Water District (LVVWD web). The native soils do not readily support non-native plant species without preparation (especially plants used for agriculture production) because of high pH levels and little organic matter (Southern Nevada Water Authority web). The local climate characteristics require high amounts of water to sustain crop production, especially in the hot dry months, precluding most agricultural activity. The region is almost entirely dependant on non-local, resource-intensive food production and distribution for its food supply because a local food growing network is virtually non-existent beyond educational and personal gardens. No established UA network was found at the time of this research; the American Community Gardening Association (ACGA) does not even show any registered community gardens (ACGA web).

Las Vegas’ reliance on non-local food is not surprising when one thinks of Las Vegas as a consumer’s paradise. The city has been built upon consumer demand for the service industry — not on the production of any tangible goods. This makes the idea of widespread agriculture production in Las Vegas seem less likely than in most cities. This is also a reason why its potential in Las Vegas is so great. Dickson suggests that combining the seemingly disparate operations of food production and urbanism is provocative and this

dichotomy is the reason it has such great potential (66). Combining farming and sustainable urbanism in a city where neither is expected by its local population is a challenge. It could be argued, however, that a BIA project in Las Vegas is less of a paradox than an ocean-inspired casino in the Mojave Desert.

While UA is not firmly established in Las Vegas, the city is an ideal location for using food production technologies, especially greenhouse food production, largely due to its average of 294 days of annual sunshine (City of Las Vegas web). CEA has proven to be a highly successful commercial business in Las Vegas, but not *for* Las Vegas. Sunco Greenhouse in North Las Vegas is a commercial hydroponic greenhouse that exports millions of pounds of fruits and vegetables out of the local food system, but no produce is shipped to Las Vegas supermarkets (Nevada Business Journal 19). Literature in water conservation points out that exporting food is the same as exporting water; the common term for this is “virtual water” (World Water Conference 3). In a region as water-poor as Las Vegas, this exportation of virtual water from the local market is a questionable practice. Using local water resources to sustain local food needs and keeping the money generated by this agriculture in the local economy could help Las Vegas become a more sustainable urban landscape.

The impact on the local economy could be significant: even if the 15 to 21% market growth rate projected by the OTA slows down to 10%, the Las Vegas healthy food market could equate to a 240 million dollar market for fruits and vegetables in 2011 based on population percentages¹¹ (Perkowski 33).

¹¹ This number can be calculated if it is assumed that Clark County’s organic food market is representative of the U.S. organic food market. Population figures can then be used to estimate Clark County’s potential market size and growth expectations and applied to yield the local market size in 2011.

Las Vegas has also been one of the hardest hit regions in the recent economic recession according to the Brookings Mountain West Monitor publication in December 2009. Unemployment, home real estate foreclosures, and a major slowing in economic activity have all contributed to a downtrodden local economy that is not aligned with the “stabilizing” national economy (Brookings Mountain West 1). This under-performance has also affected the commercial real estate market and helped to create more than 12 million square feet of vacant industrial real estate, according to Applied Analysis’ 2009 third-quarter “Las Vegas Commercial Market Monitor” (1). This is more than 12% of the available industrial space in greater Las Vegas (Applied Analysis 1). More recent studies have shown an increase in this percentage to more than 15% vacancy with no signs of recovery¹² and these numbers increase dramatically if vacant retail and office real estate are considered. This under-utilized space has created an opportunity for renters because, as the vacancies continue to rise, the rental rates are falling, and alternate uses for these buildings, such as BIA, become more economically feasible.

Locating and planning urban farms using retrofitted existing building stock to maximize food production and ease of distribution in Las Vegas requires consideration of multiple local factors related to geography, economics, and the built environment.

Research Objectives, Questions, and Methods

It is in the interest of designers to take action in securing their place in the BIA industry at this early stage¹³ because it is clear that the demand for more healthy food will support

¹² See Smith web.

¹³ This pro-active role for the architecture profession is suggested by John Peterson, founder of Public Architecture (Peterson 95).

the advancement and widespread implementation of BIA. An objective of this thesis is to provide initial insight into how the architect/designer can successfully incorporate new high-performance agriculture technologies being developed for BIA into the urban landscape.

To help achieve this objective, methods and factors for UA planning, greenhouse planning, and planning for the adaptive reuse of existing building stock were reviewed in the literature review. These planning materials were chosen because this thesis proposes that UA, greenhouses, and adaptive reuse of existing building stock are the fundamental components of BIA. The breakdown of BIA into its components was necessary because BIA is a relatively new phenomenon and little literature specific to its implementation exists. An abundance of scholarly literature was available concerning the defined components of BIA. Each of these fields provided key planning factors and criteria for integrating a successful project into the urban landscape and information on where the architect fits into the planning process. An organized table of observed planning factors and methods was developed from the analysis of the literature.

Case studies of proposals using new BIA technologies were then reviewed to help determine which factors identified in the literature review are most important in planning for a successful BIA project. The case studies examined a selection of new BIA technologies that are available as turnkey CEA systems. Each case was assessed in relation to planning factors discussed in the literature review and other factors that informed the planning process for a successful project. Analysis of the case studies revealed that each BIA system has unique opportunities and constraints for their integration into an existing site and some factors are more important than others depending on the type.

The literature and case studies were reviewed with the following questions in mind:

- 1) What factors need to be considered in locating a site for UA, greenhouse, and building adaptation projects?
- 2) Once a site has been chosen, what factors should be considered in deciding on a design for UA, greenhouse, and building adaptation projects?
- 3) What site selection and design factors are most important to consider in planning for BIA?

After each chapter in the literature review, the factors were documented and organized in an outline format. These tables were then analyzed and used as references throughout the research.

A planning process specifically for BIA was developed after analyzing the case studies. The planning process was informed by findings from the analysis of the literature and case studies. This proposed planning process outlines barriers and factors that should be considered in the planning phases for a successful BIA project to help ensure that the BIA proposal is feasible. The proposed process is especially useful for the architect/designer in deciding how and when to apply their services to the design of a BIA project.

The developed BIA planning process from this analysis was then tested in the local urban setting to better understand some of the factors determining opportunities and constraints for new BIA technologies in Las Vegas, Nevada. The results of the local study helped determine the feasibility of the proposed BIA adaptation at the site. Going through the outlined steps in the strategy also provides an example for others to use as a reference when evaluating a site's potential for a BIA project.

CHAPTER 2

LITERATURE REVIEW

Introduction

The literature review is divided into three sections that are helpful in understanding the planning process for integrating food production into the built environment. The first section is a broad review of methods and factors used in planning a successful UA project. The second section reviews multiple authors' suggestions on planning for successful greenhouses and CEA systems. The last part of this chapter briefly discusses the factors to be considered in choosing a greenhouse structure and covering material. The third section reviews selected factors in planning for a successful adaptive reuse project. Multiple viewpoints were considered in order to provide a broad body of knowledge for developing a distinct set of BIA planning factors.

Planning for UA

The process of integrating UA into unique landscapes is a common theme found throughout the literature on planning for UA. Mougeot suggests that agriculture is more or less urban depending on its integration into and relationship with the surrounding urban ecosystem¹⁴. He goes on to propose that acknowledging this concept allows for the identification of a city's "conditions and policy interventions needed, if any, to move from lesser to greater integration" (*Urban Agriculture* 11). This not only demonstrates a goal to further urbanize agriculture, but it also implies that UA planning needs to consider the unique opportunities and constraints within each city to ensure greater project integration

¹⁴ In this article, Mougeot defines urban ecosystem as both the ecological and economic systems within the surrounding city (*Urban Agriculture* 9).

with the surrounding urban systems. Bohn and Viljoen also emphasize the need to locate the individual UA project appropriately within the larger network of a productive urban landscape (240).

While each urban landscape provides unique opportunities and constraints, the literature shows that there are common factors to consider in planning for UA projects of all types. Drescher notes that the UA integration process has been carried out throughout the world and these examples provide information that can be customized for local conditions (3). Brown and Carter suggest that UA in the United States can learn from the best practices as well as the difficulties found in worldwide UA (21).

According to Vazquez and Anderson, world UA practices are commonly documented using three methodologies: 1) research based on questionnaires, 2) participatory methods and case studies, and 3) a combination of economic and ecological methods (6). Generally speaking, this is the existing body of knowledge used to define the factors that face UA projects.

Much of the literature discusses common barriers that are found in UA activities; these are also called obstacles, constraints, challenges, or issues facing UA. An authoritative study by Brown and Carter provides a comprehensive list of challenges for UA including: land tenure, start-up costs, access to markets, knowledge and skills, seasonal limits, health, urban planning, and vandalism and crime (Brown and Carter 14-17). In Drescher's study for the Food and Agriculture Organization of the UN (FAO), constraints to UA are identified as: excessive use of agricultural inputs, land tenure, and challenges to micro-finance (52). Kaufman and Bailkey group obstacles to UA into four categories: site-

related, government-related, procedure-related, and perception-related (Kaufman and Bailkey 55).

Because of the nature of their study, Kaufman and Bailkey further identified six sub-issues specific to entrepreneurial UA. These are: site contamination, vandalism, economic viability, lack of business knowledge and skills, failure to collaborate with other farmers, and UA being seen as a temporary land use (Kaufman and Bailkey 67-68). Johnson's study on entrepreneurial UA presents three common barriers to community gardening (lack of funding, lack of human involvement, and land tenure) and compares their impact on community gardening to how they affect entrepreneurial UA projects (Johnson 19). Johnson proposes that entrepreneurial UA may have an advantage in overcoming these barriers because it is directed to and working with economic development (Johnson 20).

All of the literature discussed thus far presents overlapping or similar barriers to integrating a UA project into the urban ecosystem. Collectively, these are the factors to be considered in planning for any integrated UA project. Depending on the location and the type of UA project being planned for, however, the factors carry different weight and in some cases are not even relevant. Therefore, in order to plan for a successful UA project, decisions need to be made early in the planning process about which factors to consider based on where the project is located and what type of project is being planned for. These decisions are informed by the opportunities and constraints found in the surrounding urban ecosystem. This awareness of past UA experiences and the case-by-case approach for every UA project is evident in Bhattarya's description of the site selection process:

the criteria for site selection differ on the basis of geographic location, land use pattern, physical characteristics of the land, and community needs and constraints (Bhattarya 33).

An initial step suggested by scholars to help understand and document a city's unique UA opportunities and constraints is to perform a city-wide food assessment (Brown and Carter 18). Food assessments are:

built on other kinds of assessments from the fields of community planning (asset mapping), social work (needs assessment), public health (nutrition assessment), environmental studies (environmental assessment), and international development (participatory rural assessment) (Brown and Carter 18).

Drescher proposes a similar initial assessment be performed in which certain basic requirements be met before beginning the process of planning, implementing, and improving UA. These basic requirements are:

- Creation of government and municipal awareness
- Identification of stakeholders and institutional framework (prime contact)
- Identification of main constraints to agriculture and greening
- Site survey — Identification of current and potential sites for UA
- Identification of potential for cultivation practices (Drescher 46).

Germain et al. propose a less general assessment and suggest that performing the city UA assessment is a step within the broader first step for planning gardens — defining the project (13). This guide indicates that by defining the intentions and expectations, choosing the scope of the project, selecting the type of garden, and targeting the garden's community and partners, the garden planners can then evaluate the project according to accessible resources (Germain et al. 13).

Performing these initial city assessments of the presence of UA and its resources facilitates the UA planning process in multiple ways: first, this information helps gauge the “degrees of support”¹⁵ a city has for UA (Quon 24). A city's degrees of support will provide clues as to which obstacles to UA are most significant in the city being studied, i.e.

¹⁵ Degrees of support are identified by Quon as the presence or absence of these factors: the planning institution, policy framework and cultural norms and attitudes of planners, politicians and the public (Quon 24).

which factors need the most consideration and how they might affect the proposed project. Quon further supports this by suggesting that being aware of these constraints helps the process of responding to the constraints (summary). Secondly, gathering and publishing this type of information about a city's potential for UA is known to be a valuable tool in promoting awareness and gaining support for implementing UA (Brown and Carter 18). Lastly, the literature suggests that these types of assessment records can help lead to the inclusion of agriculture in future planned uses for the land (15).

The importance of incorporating UA into local planning and policies can not be overstated because it has been found that “clear and well-publicized” land-use regulations help to ensure the UA project will be accessible to the farmer (Mougeot, *Growing Better Cities* 53). It has also been shown that many communities have been successful as a result of using policy and planning tools to address land tenure (Pohl- Kosbau 2007, qtd. in Milburn and Vail 4). Many involved in UA do not own the land they use to grow food and the inability to secure land tenure due to financial or political constraints can cause “guerrilla” or “opportunistic” gardening which is, in most cases, illegal (Mukherji 22, Quon 25). Without title or three to five year leases, the farmers risk losing their investment when the land is taken for other purposes (Brown and Carter 15).

Throughout the literature, the most emphasized factors to consider in most UA activities and assessments are issues pertaining to land; especially the key issues of availability, accessibility, and suitability (Drescher 4, Mougeot, *Growing Better Cities* 51-53, Quon 24). These land factors are relevant in all cities for all UA project types when planning for a successfully-integrated project because issues specifically related to land are the cause of many constraints to urban farming (Quon 24).

Based on previous UA projects, a widely recommended first step in planning is to take stock of the city's available land (Balmer et al. 11, Drescher 46, Grimm 30, Mougeot, *Growing Better Cities* 51, Quon 24, RUAF 4). Establishing what lands are available for food production is an important first task because it helps determine the types of UA projects and the extent to which they can be supported. In addition to available land, UA scholars also include vacant urban space in land inventories. Michaels and Mougeot suggest that food production in the urban landscape is not limited to land but should also include under-utilized space in and on buildings (Michaels 219, Mougeot, *Growing Better Cities* 53). The addition of building space to inventories is due to advances in production technology (such as BIA) which have made it possible to utilize vacant space because "systems exist for all growing environments" (Mougeot, *Growing Better Cities* 54).

Geographic Information Systems (GIS) were repeatedly discussed as useful tools for finding and mapping the inventory of available lands (Balmer et. al. 21, Bhattacharya 34, Colasanti 18, RUAF 5). Specifically, GIS offer good opportunities to integrate data from various sources and allow effective planning (Drescher 53). They also help the mapping process of available sites which, according to Colasanti, provides another way to look at the range in vacancy levels (89). An example of GIS data is shown below in figure 1:

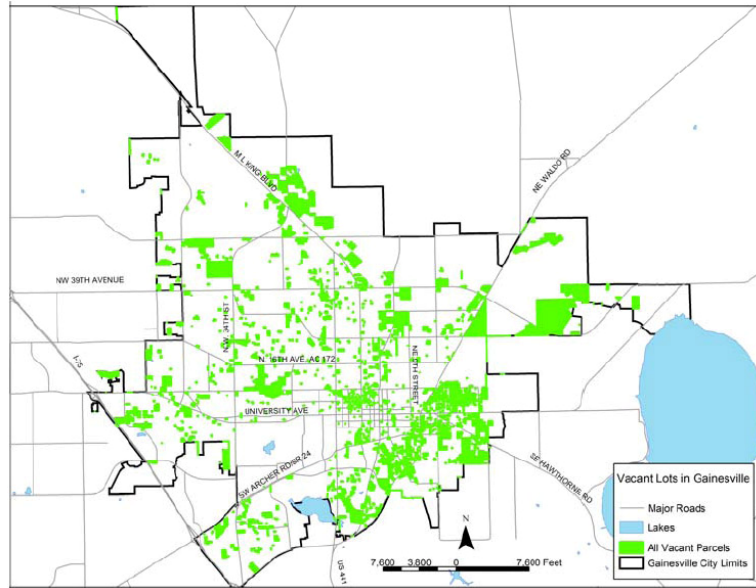


Figure 1: An example of GIS data being used to identify available lands for UA (Bhattarya 21).

Another important land issue in addition to land availability is land access. Helmore and Ratta suggest that land may be available in a city but not accessible because of political or social constraints (qtd. in Quon 25). Land accessibility may refer to both the land itself and/or to the use of the land (Quon 25). Land suitability, or usability, is yet another critical land issue which refers to the inherent qualities of a plot of land and the services available on it (Quon 25). Some scholars suggest these characteristics, especially accessibility, require more consideration than land availability because land accessibility is considered more of an obstacle to UA farms than land availability and suitability (Mougeot, *Growing Better Cities* 53, Quon 25). This is due to the UA reality that agriculture in urban areas typically suffers greater ecological and economic pressures than rural agriculture, requiring more intensive and better controlled production to stay competitive and secure (Drescher 4, qtd. in Quon 24).

Two studies in the literature with different objectives provided similar examples of methods for performing the initial available lands survey. The Portland Public Lands Inventory collected GIS data on available vacant sites provided by four local government bureaus¹⁶ with no immediate management plans (Balmer et al. 21). Colasanti's study for city-wide UA in Detroit, Michigan, also utilized GIS data provided by the City of Detroit¹⁷ which documented vacant parcels of land (82). Colasanti verified the accuracy of the GIS data by cross-checking against aerial images of Detroit and found minimal discrepancies (83).

Once the pool of available land and space was initially identified in these two studies, criteria based on obstacles to UA were used to limit the inventory of available urban spaces to only those that were accessible and suitable for UA activities because “not all vacant space is suitable for food production” (Mougeot, *Growing Better Cities* 51).

Accessibility and usability were addressed in the Portland Public Lands Inventory by deleting parcels that had no access, were slivers, or obviously unusable (Balmer et al. GIS-1). Other criteria that reduced the inventory were sites that had other planned land uses, namely the sites that fell into Environmental Zones and Parks Developed areas, and also sites that were leased by private parties with unknown lease arrangements (Balmer et al. GIS-3, GIS-5).

Colasanti's land inventory addressed accessibility and usability by excluding properties with abandoned buildings and also limiting the inventory using the following criteria:

¹⁶ The four bureaus were: Environmental Services, Parks and Recreation, Transportation, and Water (Balmer et al. 21).

¹⁷ Specifically, the data was provided by the City of Detroit Information Technology Services Department Geographic Information Systems Sales & Service Center (Colasanti 82).

Only fully vacant parcels located within city limits and owned by the city, the county, the state, the county land bank or the state land bank were considered... and all parcels owned by the City of Detroit Recreation Department were excluded (Colasanti 83).

Not all studies used existing vacant land maps to identify the inventory of potential sites. Bhattarya's study identified all potential sites for community gardening by multi-criteria analysis using available GIS data because an existing inventory of potential sites was not readily available in Gainesville, Florida (59). The criteria for available land identification in Bhattarya's inventory was based on criteria found in the literature review that addressed all three land issues — availability, accessibility, and usability. These criteria included: soil characteristics, slope, sunlight/no shade, distance from major streets and bus stops, nearness to bike paths, parcel use/zoning, ownership of land, environmentally healthy locations, demographic factors, and park deficiency substitution (Bhattarya 58). She found that not all of the criteria were applicable to her location in Gainesville, Florida, and excluded slope and access to sunlight (Bhattarya 59).

Drescher's guide to planning for UA also addresses the three major land issues in the first step, "Evaluation of Basic Criteria" (46). At this stage, Drescher recommends that the availability of space for UA should take into account tenure conditions, water availability, soil conditions, previous land uses, and farming systems analysis (46).

All of the studies in the literature developed or recommended the development of an inventory of the available, accessible, and suitable lands using applicable criteria. After this step, the inventories were used in different ways to achieve specific research objectives. Grimm and Balmer et al. developed their inventories and applied further evaluative criteria to the inventoried sites to assess the types of UA that were best suited for

the sites. The objective in these studies was to develop a typology system to classify the use of the sites (Balmer et al. 21, Grimm 33).

In Balmer et al.'s land survey, the developed typology was intended to be used as a resource for identifying the potential for UA in Portland and in a broader sense to increase the planning focus on UA and facilitate its implementation (13). The following evaluative criteria were used to classify the inventory: tenure of land, water access, level grade, transit access, and proximity to other agricultural activity, while soil quality was not tested (Balmer et al. 22). "The data analysis did not remove sites based on the criteria developed, but instead attributed the data with the information (developed criteria) so that it could be used in a way that was suitable for each individual use" (Balmer et al. 11). The evaluation produced this useful typology:

Table 1: Urban Agriculture Categories

Category	Community Gardens	Small-Scale Growing Operations	Large-Scale Growing Operations	Growing on Impervious Surfaces or Poor Soil
Agricultural Uses	Gardens with individual plots; gardens with shared gardening space	Farm stands, educational gardening programs, composting, vermiculture, food bank gardening, herb growing, beekeeping, pocket garden, floriculture, market gardens	CSAs, other urban farms, urban orchards, animal husbandry, Zenger Farm immigrant farmer apprentice program, horticulture, native plant production, nursery, beekeeping	Vertical gardening; indoor growing (e.g. sprouts, mushrooms, aquaculture, vermiculture); greenhouses, farm stands, community processing, farmers' markets, container gardening, hydroponics

Figure 2: Developed UA typology system for available lands in Portland, Oregon (Balmer et al. 23).

The category, "Growing on Impervious Surfaces or Poor Soil," was identified as parcels with more than 5,000 square feet of impervious surface which constituted more than 15% of the total surface area (Balmer et al. GIS-11). This was assessed using the provided GIS data along with analysis of aerial photographs and visits to selected sites (Balmer et al. GIS-10).

In Bhattacharya's study for Gainesville, Florida, the objectives were:

1. Devising a strategy for identifying new potential community garden sites,

2. Identifying and inventorying existing community gardens in Gainesville,
3. Evaluating new and existing potential community gardens against devised strategy (58).

Basic criteria were applied to the developed land inventory using the planning process “Sieve mapping” (Bhattarya 59). The criteria (sieves) used to identify the potential sites for gardening and eliminate ones not fit for gardening were: vacancy, well-drained soils, suitable zoning and public ownership (Bhattarya 59). These factors were categorized as “basic” criteria (Bhattarya 59). Bhattarya’s identification process, however, was a two-part method which used a second set of criteria to further limit the number of potentially suitable garden sites. These “secondary” criteria (sieves) were used to meet the objectives of accessibility, environmental health, service to special populations, and consistency with stated public policy (64). These were broken down to meet seven finer criteria: within 100 feet of a bike path, within a five minute walk to a bus stop, within a ten minute walk to a bus stop, 100 foot buffer from major roads, neighborhoods that are below the poverty level (>20%), neighborhoods that have a higher density of people aged 65 years or older (>20%), and sites not within a buffer of 0.25, 0.5 and 1.5 miles of an existing park (64-70). Bhattarya’s process is diagramed below in figure 3:

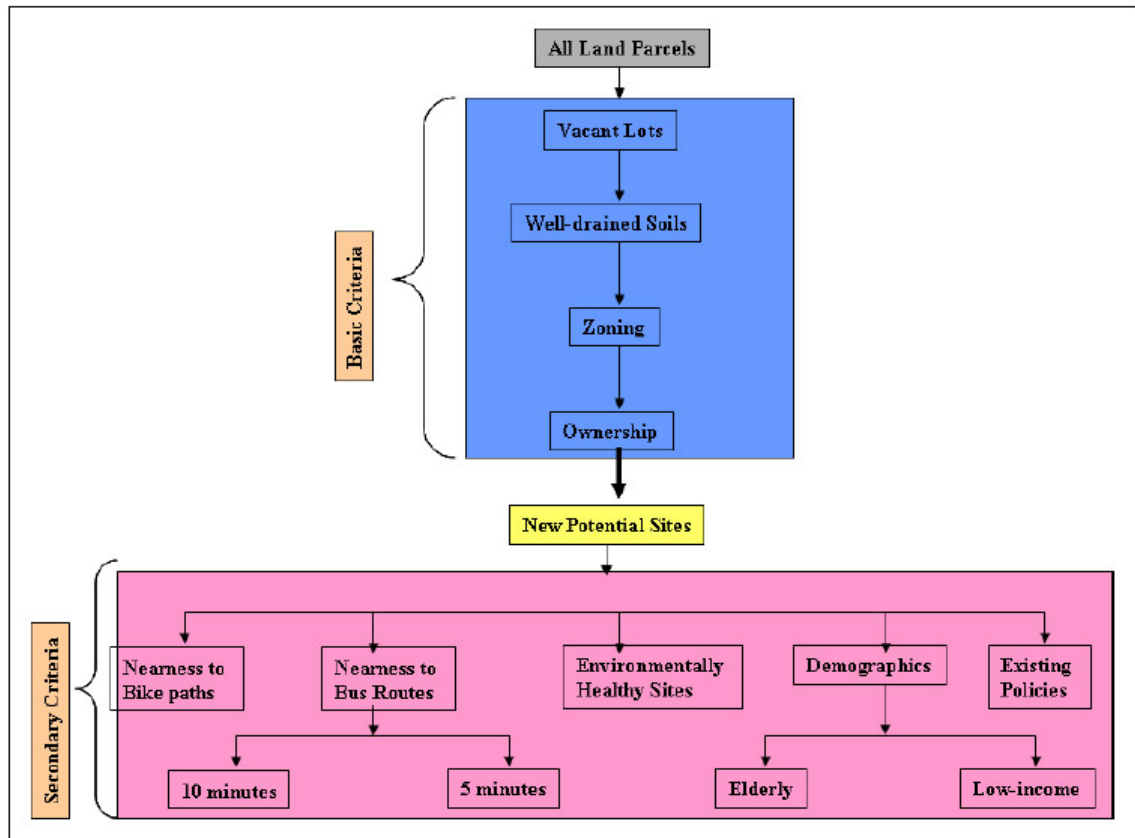


Figure 3: Bhattarya’s developed strategy for identifying potential community gardening sites (59).

As described above, Drescher’s strategy for planning, implementation, and improvement of UA developed the inventory of available lands as part of its first recommended step — the evaluation of basic data (46). This planning strategy is to be used as a tool to address the constraints to UA in urban areas throughout the world. The second step in the strategy is titled, “Stakeholder Analysis” (Drescher 47). Drescher suggests it is necessary to identify all stakeholders that will be involved in the project to help the farmers organize themselves (47). This includes everyone from the farmers and land owners to the project donors and the local authorities. The third step in this strategy is to identify the fields of intervention (Drescher 47). This step includes identifying which farming modules should be promoted; assessing whether the site allows for vegetable

production, livestock, aquaculture, and/or urban forestry (Drescher 47). Drescher notes, “it is more efficient to promote already existing modules and help to improve them, instead of creating new, artificial modules which are not known to the stakeholders, not adapted to the local situation or not accepted” (47). The fourth and final step is the “analysis of technical issues” and especially the role of extension services (Drescher 48). Here Drescher asks what are the most suitable practices in terms of typical farming issues such as irrigation practices, integrated production systems, integrated pest management (IPM), and even book-keeping (48). Another issue to be addressed in this step is to identify the infrastructure that is needed (Drescher 48).

This strategy, much like others found in the literature, suggests a broad to narrow approach to the planning process for UA, from addressing the urban constraints and opportunities to addressing site issues.

The existing body of knowledge about planning for UA is especially significant for designers/architects that become involved in the process because UA scholars suggest that the architect’s role is “a complicated one, requiring distinctive and discerning skills: listening rather than telling and catalyzing rather than directing... because the culture that the design expresses is largely given rather than imposed” (Crouch and Wiltshire 130). UA practitioners are apprehensive about turning over the planning process entirely to “the ministrations of the architectural profession” because of their views on the new modernism (Crouch and Wiltshire 130). Crouch and Wiltshire suggest that the architect’s role is not to reinvent the site-selection process but rather to use his or her spatial design skills to help create more functional UA allotments and use urban planning skills to integrate UA sites into the urban landscape in creative ways to “achieve valuable synergistic effects” (131).

Barrier Category	Factor	Reference
Geography		
Physical	Land suitability, Seasonal limits	(Mougeot, <i>Growing Better Cities</i> 53), (Quon 25), (Brown and Carter 14-17)
Human	Land tenure, Land availability, Land accessibility	(Brown and Carter 14-17), (Drescher 52), (Johnson 19), (Mougeot, <i>Growing Better Cities</i> 53, Quon 25)
Economics		
Production	Type of garden, Agricultural inputs, Vandalism	(Germain et al. 13), (Drescher 52), (Brown and Carter 14-17), (Kaufman and Bailkey 67-68)
Distribution	Access to markets, Collaboration with other farmers, Business knowledge and skills	(Brown and Carter 14-17), (Kaufman and Bailkey 67-68)
Finance	Start-up costs, Viability, Funding	(Brown and Carter 14-17), (Kaufman and Bailkey 67-68), (Johnson 19)
Built Environment		
Site Infrastructure	Water access, Existing structures	(Michaels 219), (Mougeot, <i>Growing Better Cities</i> 53), (Drescher 48)

Figure 4: Table of barriers to UA and the associated factors to be considered in the UA planning process.

Greenhouse and CEA Planning

Unlike many types of UA projects, Controlled Environment Agriculture (CEA) is almost always approached on a commercial scale to overcome its basic limitation: cost (Dalrymple 2). The amount of control used in commercial operations is often less than the potential due to cost limitations, “but at the very minimum, the presence of a greenhouse provides the basis for control greater than that of traditional field agriculture” (Dalrymple 17). In 2008, the North American Greenhouse Hothouse Vegetable Grower Association (NAGHVGA) defined greenhouse production systems as “fixed structures with glass or impermeable plastic which implement computerized irrigation and climate control systems,

uses [sic] soilless media and hydroponic methods, and practices [sic] integrated pest managements (IPM)” (qtd. in Fitz-Rodriguez 14). Hydroponic greenhouses fit this description and can also be classified as CEA systems (Fitz-Rodriguez 14).

Even though the greenhouse is a minimal environmental control, it is still more expensive than traditional field-based agriculture and therefore its use should be limited to areas where 1) local crops are expensive or of low quality, or 2) local production is not possible (Dalrymple 5). Other sources (Shrethsa and Dunn, Donnan, and Tyson et al.) also state that traditional field agriculture should not be overlooked because of the higher costs associated with greenhouse production¹⁸.

Hydroponic greenhouses, though expensive, have been successful in desert and arid climates in part because these areas have abundant sun, mild winter temperatures, infrequent violent weather (tornadoes, hail, and excessive snow), and low humidity in the summer for air cooling (Dalrymple 73). Since the 1970’s, they have been seen as a definite commercial possibility for desert regions because of highly successful examples in Arizona and Abu Dhabi (Dalrymple 42).

As shown in figure 5, generally the pre-production phase is the first step in planning for a greenhouse. This phase begins with long-term planning consisting of the site selection and greenhouse design (Fitz-Rodriguez 17). In discussing the planning process for a greenhouse, Hochmuth stresses the importance of the pre-production planning considerations because greenhouse vegetable production involves a great amount of risk (Hochmuth et al. HS773). Nearly every source encountered in the literature review first introduces hydroponic greenhouses as a business that, if run correctly, can be more

¹⁸ See Shrethsa and Dunn p. 4, Donnan web, and Tyson et al. p. 6.

intensive and more productive than any other growing system (Dalrymple ix, Jensen 13, Shrethsa and Dunn 1, Tse 6). Exactly how much more productive hydroponics is in relation to open field agriculture is up for debate because different growing technologies are able to achieve different levels of intensity, but a reliable number is provided by one of the U.S.'s leading commercial greenhouses: Eurofresh Farms claims to be up to 10 times more productive than traditional field agriculture (Eurofresh Farms web). Achieving this level of productivity requires careful planning and managing of local and internal constraints and leaves "little room for error" (Jensen 13).

The literature offers different levels of explanation, however, of how to plan a profitable and maximally productive greenhouse business and the extent to which site selection and greenhouse design affect its success. Fitz-Rodriguez cites Costa and Giacomelli who suggest that, "although a high productivity with high quality produce is always desired, a high technological level is not always economically feasible for all climate conditions and for all markets. A proper selection must be based according to [sic] the local climate conditions and to the targeted market, while assuring a [sic] technical support in all aspects of the crop management" (15).

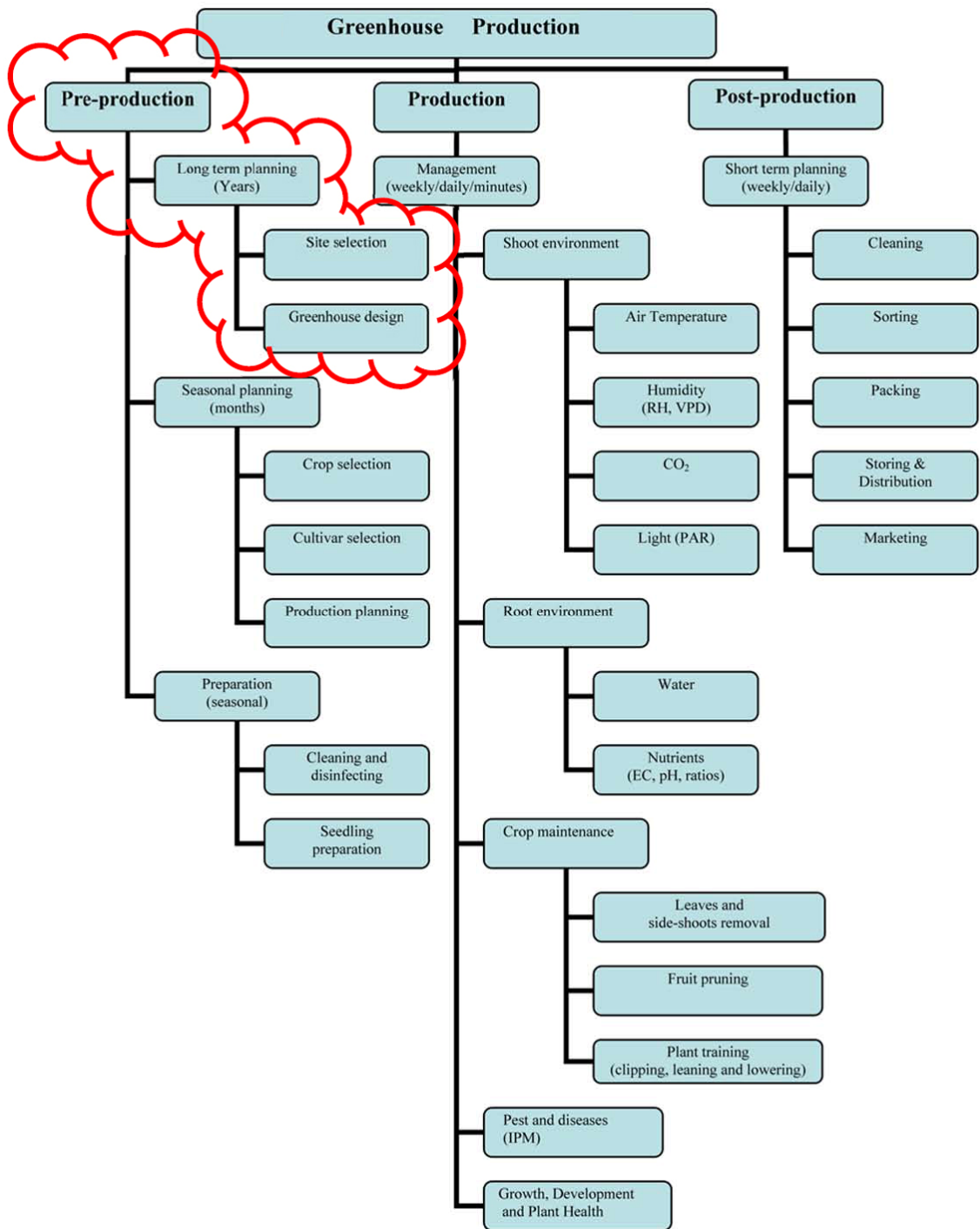


Figure 5: This conceptual diagram documents one scholar's efforts to organize the planning strategy into a decision support system for greenhouse production (Fitz-Rodriguez 18). The highlighted area signifies the beginning planning factors.

One source merely suggests that the high initial costs incurred are a sound investment because of the high productivity potential (Tse 6). This is the extent of economic analysis provided by Tse. In Tse's discussion, the local market conditions are not included in the process of locating a site for the greenhouse; instead, making the greenhouse maximally productive through its location and design is emphasized. Tse proposes the first step in planning is to locate the greenhouse using the following factors: topography, orientation, water supply, accessibility, room for expansion, and even future land use prediction (6).

While these are worthy physical and political factors to consider in the site selection and site design process, many other scholars emphasize economic considerations at the beginning of long-term planning and imbed them in the site selection and greenhouse design process.

Donnan barely addresses the site selection process but discusses the business planning and greenhouse design in depth. He recommends starting the planning process with an analysis of the market (web). The market is analyzed by addressing questions such as, "Where do you intend to market the crop? What are the requirements of the buyers? Where does your proposed market currently get its supply, and is the market static or developing?" (Donnan web). The entire planning process is proposed as a cyclical process and works through this sequence of steps:

- the market
- the crop
- the growing environment
- the growing system
- management
- financial analysis (Donnan web).

Donnan also does not address greenhouse design in-depth and the little information that is provided about it is very basic. Designing the greenhouse is addressed in the “growing environment” step in which he suggests considering the local climate in deciding whether a protective structure is needed (Donnan web). If protection is needed, Donnan lists general factors to consider in choosing a structure, such as “ability to perform as claimed; versatility; ease of construction; cost as delivered; installed cost; maintenance cost; heating and/overcooling costs; and vulnerability to storm damage” (web).

Donnan reviews factors in managing a hydroponic greenhouse and reviews typical issues facing new greenhouse growers. The only site factors discussed in this article are access to a good water supply and the existence of building regulations (web).

Giacomelli also summarizes the relationship between strategic planning and the design of the greenhouse with little mention of the site selection process:

Selection of the greenhouse design is determined by the expectations, needs and experience of the grower. Consider what crop(s) will be grown, how they will be managed, and the grower experiences in the type of growing system. With this initial information, a workable design can be completed, and then modified by the financial realities of the required investment (Giacomelli web).

Hochmuth et al. precede the site selection with in-depth financial considerations to determine the cost of a greenhouse. They state that the cost of establishing the operation depends on the following factors: the size and number of the greenhouses, type of production system to be used, method of marketing, need for associated facilities such as packing facilities and vehicles, availability of supplies and support services, and amount and quality of labor (Hochmuth et al. HS767). They argue that only after these factors have been addressed can an informed site selection process begin.

While Hochmuth et al. provided a review of financial considerations, Jones provides suggestions on the site selection process. Building on the information in his financial planning chapter, Jones provides a list of factors to consider in determining the suitability of a site, or group of potential sites, for the proposed project: regulations and services, water availability and quality, physical site requirements, and forward planning (Hochmuth et al. HS775). These articles illustrate how financial considerations and site selection factors build on each other.

A publication by the Manitoba Agriculture, Food and Rural Initiatives group also offers key long-term planning questions to develop the business strategy and operation, as well as market opportunities.

- Who will be my customer?
- What will I produce?
- When will I operate the greenhouse?
- Where should I build?
- Why a greenhouse? (web).

These questions help to determine the type of operation and to avoid building a structure that does not fit the farmer's future needs (Manitoba web). The type of operation, whether wholesale or retail, will determine the type, size, location and layout of the greenhouse (Manitoba web). The guide then discusses the difference between these two operation types:

a retail operation needs to consider factors such as location, proximity to a large market, zoning, health regulations, retail license, signs, accessibility, liability insurance, good roads, customer parking, and facilities to accommodate the public. A wholesale operation is less dependant on a prime location, however, proximity to market needs to be considered when determining transportation costs. A wholesale operation also limits the type and variety of crops grown and limits the marketing base (Manitoba web).

The Manitoba publication further advises developing a sound business plan (Manitoba web). Within the business plan, a marketing strategy is developed which should consider the following points:

- a) Research your customers. Know what they want and when they want it.
- b) Determine what is available in your area and who is producing it.
- c) Identify niche markets.
- d) Determine the type of outlet that best suits your personal ability and services the identified needs of the area. (Wholesale vs Retail)
- e) Determine your ability to produce for the market at a return that covers your expenses.
- f) Determine how much time you are willing to spend in this operation and be prepared for unforeseen situations. (Manitoba web).

The Manitoba publication clearly combines marketing and business operation type to inform the site selection and greenhouse design.

The West Virginia University Extension Services also suggest that the type of business operations, whether wholesale or retail, is a significant factor in the site selection process. Retail operations require a location on a well-traveled road, near major highways or within 20 minutes of consumers since proximity to customers increases customer traffic, whereas wholesale operations should be located where zoning restrictions will not limit expansion of the operation (West Virginia University web). Kessler also adds that a retail greenhouse should be visible to customers from at least 200 feet (3).

A University of Arizona Controlled Environment Agriculture Center (CEAC) publication describes a community profile to be assessed prior to selecting a site that goes beyond business planning and marketing strategies. A community profile should be gathered for potential sites from the city or area Chamber of Commerce (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-3). The information reveals local considerations that affect long-term planning. The profile should contain:

- Community background information: location, elevation, history and weather
- Population, employment structure and labor force information
- Growth indicators, principal economic activities and property tax information
- Available properties, financing, transportation, communications and utilities
- Government, medical and educational services
- Listings of area churches, recreational facilities and lodging
- Area attractions including scenic parks, drives, etc., historic sites, annual events, etc. (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-3).

Once this information is available, the University of Arizona CEAC suggests 12 factors to consider for selecting a greenhouse site which will increase the chance of a successful operation and business: 1) solar radiation, 2) water, 3) elevation, 4) microclimate, 5) pest pressure, 6) level and stable ground, 7) utilities, 8) roads, 9) north-south orientation, 10) capability of expansion, 11) availability of labor, and 12) management residence (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-2 – 11-3).

Also from the University of Arizona CEAC, Giacomelli adds to the set of site selection factors that the land should be well-drained and level, and have access to roads for transport of materials and products (web). Utilities such as fuel, electrical power and telephone should also be readily available and sufficient quantity of good quality water is a necessity (Giacomelli web). In laying out the site, Giacomelli suggests planning for a greenhouse range to make the most efficient use of the available space by “beginning with a small, but complete, free-standing greenhouse unit, which readily fits within a plan for future additions to this initial unit, or with modular blocks of separate, larger greenhouses” (Giacomelli web). Tse also advises to include extra land space in the planning to cater for possible future expansion (8).

Bartok provides a useful comprehensive list of factors for anyone starting a small commercial greenhouse or adding to an existing facility. He summarizes the considerations for the entire planning process, from site selection to the site layout and greenhouse design, for a successful project. The factors are presented in a general order of importance. For Bartok, the most important considerations for site selection are: adequate land, high quality water, orientation, topography, road accessibility, utilities, and regulations (354). Bartok also provides a list of site layout factors that are presented in order of importance: facilities master plan, parking and access, storage, and production areas (355).

The greenhouse design is considered next in Bartok's process, because "a key to successful production is a well-designed greenhouse with good space utilization and accurate environment controls" (355). The factors in greenhouse design are: glazing type, layout, germination rooms, and whether the structure is to be free-standing or gutter connected (355-356). Greenhouse design also requires planning for a controlled environment which should consider: heating and cooling, energy conservation, supplemental lighting, controls, irrigation, and pesticide and fertilizer storage (Bartok 356-357).

Bartok's guide proposes that there is a general process to be followed in planning for a greenhouse: once a site is selected, an analysis of the site is to be performed and then an analysis of suitable greenhouse designs is to be performed.

Tse uses schematic-level diagrams to illustrate the assessment of site opportunities and constraints and help determine the location and type of greenhouse construction that is most suited for the site. His diagrams document local climatic factors, such as solar exposure and wind patterns, and demonstrate how they can affect the location of the

greenhouse and the overall master plan of the site. In figure 6, Tse illustrates the importance of positioning the greenhouse on the site in a non-shaded location, out of the path of wind funnels caused by adjacent buildings, and protected by natural windbreaks:

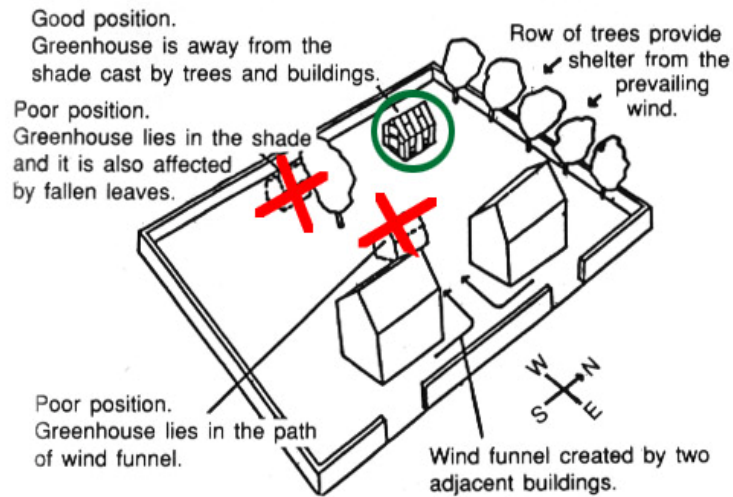


Figure 6: Tse's diagram of site layout factors and correct placement of a free-standing greenhouse (9). Color has been added for clarity.

Figures 7a and 7b show Tse's illustrations of solar radiation studies that demonstrate proper greenhouse orientation based on latitude, seasons of greenhouse operation, and greenhouse style. He suggests that greenhouses located above 40 degrees south latitude and/or greenhouses used mostly in the summer should be oriented north to south to make the best use of the higher sun angle (figure 7a). He also advises that this north-south orientation is preferred for sawtooth¹⁹ greenhouses at all latitudes (Tse 7). For greenhouses below 40 degrees south latitude, Tse suggests orientation with the long side running east to west to take advantage of the lower sun angle as shown in figure 7b (7).

¹⁹ See figure 11 for illustration of sawtooth greenhouse.

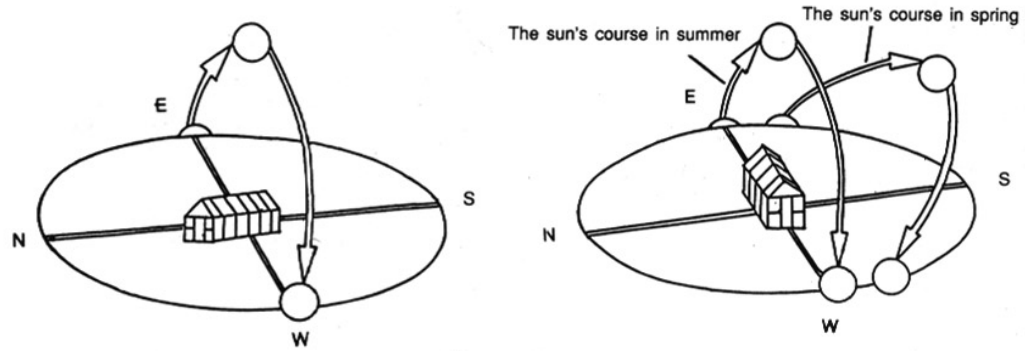


Figure 7a & 7b: Two demonstrations of a daylighting analysis. The first diagram illustrates optimal greenhouse orientation for sawtooth greenhouses at all latitudes. The second graphic shows optimal greenhouse orientation for year-long greenhouse production in locations below 40°S latitude (Tse 8).

Tse also suggests avoiding areas that are shaded by existing structures on the site for the greenhouse location. Ross, however, demonstrates the use of schematic diagrams to verify where shading occurs. This helps to ensure the proper placement of the greenhouse on the site in non-shaded areas. As seen in figure 8, Ross illustrates summer and winter shading issues caused by a structure near the greenhouse:

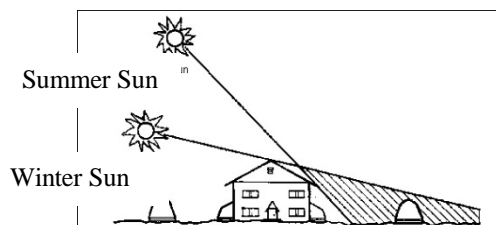


Figure 8: Example of an annual site shading assessment diagramed in elevation (Ross 2).

Ross discusses locating a greenhouse on a site with existing shading structures in more detail than Tse and provides recommendations for the best options available depending on the site constraints. For example, his first choice of location is the south or southeast side of a building or shade trees (Ross 1). He reasons that the east side provides the most morning sunlight and sunlight in the winter months and so it is preferred for optimal plant

growth. If the east side is not available as a greenhouse location on the site, however, the next best location is on the southwest or west side of major structures (Ross 1). The least desirable location on a site, he argues, is on the north side of a major structure unless the crops require very little light (Ross 1). While Tse and Ross go into different levels of detail regarding locating a greenhouse on the site, they agree that the natural load factors such as wind and solar exposure, as well as drainage, affect the site layout design and overall master plan.

Kessler offers a different approach for planning the site layout. He uses the type of business, whether wholesale or retail, to determine the layout of the site and almost completely neglects natural load factors. He suggests, “In a wholesale production greenhouse, the primary factor to consider in arranging buildings and equipment is materials flow and how it impacts labor utilization and future expansion” (Kessler 4). Kessler’s layout of a wholesale facility would look like this:

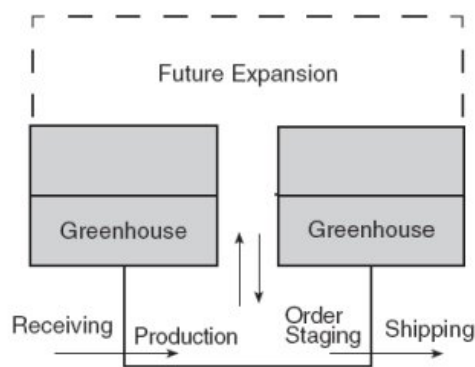


Figure 9: Site plan for the arrangement of a wholesale greenhouse and support facilities (Kessler 4).

The wholesale arrangement is different from the retail because “materials flow is also important in a retail operation, but customer movement and access are also critical”

(Kessler 4). The materials flow considerations he provides for retail are pragmatic; he recommends analyzing how the product gets from the delivery truck to the consumer's vehicle (Kessler 4).

Once the site layout is planned, most of the literature sources follow with discussions on greenhouse style and structure (see Bartok, Bucklin, Kessler, Ross, and Tse). There is evidence that the structural design choice should be based on industry-standard construction types because “there has been little change in the design of the basic greenhouse structure over the last decade” (Jensen 11). Tse asserts that the most common greenhouse framing materials are wood and especially aluminum which is superior because it is strong, lightweight, and affordable (12). Some of the most common greenhouse types are presented below:

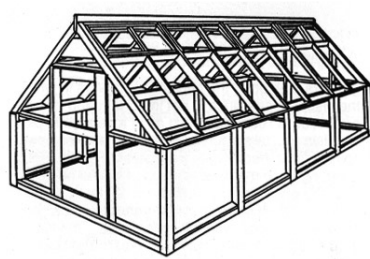


Fig. 3a 'A-frame' or 'even-span frame' greenhouse

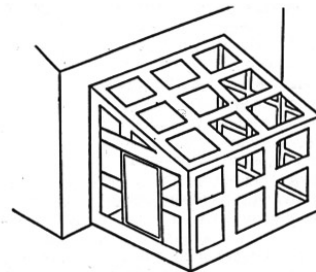


Fig. 3b 'Lean to' greenhouse

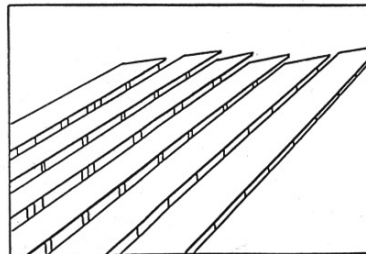


Fig. 3c 'Sawtooth' greenhouse

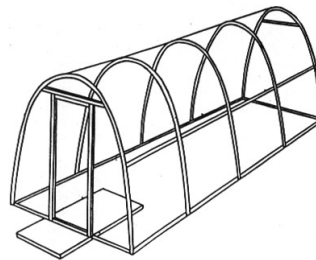


Fig. 3d Tunnel house

Figure 10: Framing illustrations of typical “A-frame” or “even-span” greenhouses, the attached “lean-to” greenhouse, the “sawtooth” connected greenhouse, and the “tunnel” or “Quonset” greenhouse (Tse 12-13).

It is important to note that any of the reviewed protected greenhouse structures can be part of a turnkey package customized to the grower's needs. These packages have become increasingly popular and offer total systems of the protected structure, hydroponic and support systems, and often include consulting and marketing agreements (Shreshtha and Dunn HLA-6442-4). These packages can guarantee optimal growing environments in any of the protected structures for using new, highly efficient, food production technologies. Therefore the review focused on how the greenhouse structure aesthetically and functionally fits into the context of the site rather than reviewing interior environmental controls and space planning issues.

Barrier Category	Factor	Reference
Geography		
Physical	Topography, Orientation, Climate, Land space for future expansion, Solar radiation, Elevation, Wind patterns	(Tse 6-9), (Ross 1-2), (Fitz-Rodriguez 15), (Jensen HS775), (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-3), (Giacomelli web), (Bartok 354), (Kessler 4)
Human	Accessibility, Future land use predictions, Regulations, Community history, Available properties	(Tse 6), (Jensen HS775), (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-3), (Bartok 354), (Kessler 3-4)
Economics		
Production	Space versatility, Vulnerability to storm damage, Grower expectations, Grower experience, Size and number of greenhouses, Crops to be produced, Type of production system, Availability of supplies and support services, Availability of labor, Pest pressure, Management residence, Environmental controls, Energy conservation, Seasons of operation	(Donnan web), (Giacomelli web), (Hochmuth et al. HS767), (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-2 – 11-3), (Bartok 356-357), (Ross 1), (Kessler 1-12), (Tse 7)
Distribution	Target market, Marketing methods, Delivery vehicles, Packing facility, Operation type, Road access, Storage, Materials flow	(Donnan web), (Hochmuth et. al. HS767), (Manitoba web), (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-2 – 11-3), (Giacomelli web), (Bartok 355), (Kessler 1-12)

Finance	Capital costs, Operating costs, Viability, Property taxes	(Dalrymple 5), (Shrethsa and Dunn 4), (Donnan web), (Tyson et al. 6), (Rorabaugh, Patricia A., Merle H. Jensen, Gene Giacomelli 11-3), (Ross 1), (Kessler 1-12)
Built Environment		
Site Infrastructure	Water supply, Site plan layout, Ease of construction, Utilities, Parking, Existing structures, Headhouse	(Tse 6), (Donnan web), (Rorabaugh, Patricia A., Merle H. Jensen, and Gene Giacomelli 11-3), (Giacomelli web), (Bartok 354), (Ross 1-8), (Kessler 1-12)

Figure 11: Table of barriers to greenhouse and CEA planning and the associated factors to be considered.

Planning for Adaptive Reuse of Existing Building Stock

Currently, abandoned and underutilized structures increasingly have an impact on the urban landscape. Real estate market reports for Las Vegas show that the industrial and commercial real estate markets have growing vacancy percentages²⁰. Further, the American Institute of Architects (AIA) Architecture Billings Index for July 2010 shows that billings have not reached growth threshold for more than a year (Riskus web, Baker web). This has forced architects to diversify their clientele and search for specialty niches in the construction industry and as Cortese observes, “Beyond specialty niches, some architecture firms are banking on commissions to refurbish or adapt existing properties, in lieu of new construction” (13).

According to Reiner, existing building stock has been one of our most neglected resources (ix). Contemporary architects also agree that there is great opportunity in the existing building stock (Cortese 13). This is especially true because of the lack of new

²⁰ See page 10 for further discussion about the current Las Vegas economy.

construction projects, a growing number of vacant buildings, and the increasing amount of literature promoting the benefits of adapting existing buildings.

Some of the suggested advantages of building adaptation include: economic benefits due to lower construction and demolition costs, environmental benefits due to a reduced amount of new material use and of waste generated, and social (or architectural) benefits due to the preservation of our built heritage²¹ (Douglas 36-38, Watson 218-219).

Adaptive reuse of existing building stock can thrive in the current construction recession and help to create a more sustainable urban landscape. In fact, one of the leading voices in building adaptation contends that, “Adapting buildings is an important component of any sustainability strategy” (Douglas 46).

First, Douglas clarifies what is meant by “building adaptation”:

In general terms adaptation means the process of adjustment and alteration of a structure or building and/or its environment to fit or suit new conditions... it is also considered as work accommodating change in use or size or performance of a building which may include alterations, extensions, improvements, and other works modifying it in some way (1).

After Douglas provides a background on building adaptation, which include pros and cons of adaptation, reasons for vacancies and building obsolescence, and the different types of adaption that can be performed, he provides a list of five key requirements for a sustainable property that should be considered in the decision to adapt any building:

1. the building should have a long life (i.e. be durable – to resist wear and tear);
2. it should have a loose fit (i.e. be adaptable – to accommodate future changes);
3. it should have a low [sic] energy consumption (i.e. be thermally efficient – low running costs);
4. it should be wind and watertight (i.e. be weatherproof); and

²¹ See Douglas and Watson for complete discussions on the benefits of adapting existing building stock.

5. it should provide a secure and healthy indoor environment (i.e. be comfortable) (Douglas 41).

Next, Douglas discusses means of ascertaining the feasibility of adapting buildings (48). He offers three primary feasibility factors to consider in the preliminary evaluation of a building for adaptation: viability (economic feasibility), practicality (physical feasibility), and utility (functional feasibility) (Douglas 48).

Viability is usually the deciding factor for adapting a building. It is assessed by comparing potential value with project costs because it may be technically and legally possible to adapt a building but at a prohibitive cost (Douglas 48-49). Practicality is concerned with the building being “capable of adaptation without major or long-term disruption to either its use or its structure and fabric” (Douglas 52). Douglas also proposes that many times practicality is influenced by the extent of the access required for the work; for example, congested urban sites are more complex to plan (52). Utility, as described by Douglas, is concerned with providing a building that fits the occupants’ needs while minimizing wasted underused space without overusing the available space (52). He also suggests planning for possible future changes is also a utility issue (Douglas 52).

Douglas suggests the type of construction of a building also helps determine feasibility whether it is traditional or modern construction will have a large impact on its potential for adaptation (Douglas 58). He points out that traditional construction may not have readily available drawings of the existing building conditions and information on old or obsolete construction methods may be difficult to find; whereas “as-built” drawings are usually available for modern buildings (Douglas 58).

Once the construction type is assessed, Douglas lists other adaptation issues that need to be addressed for a thorough understanding of the building. These other adaptation issues

are: site usage and density, layout and configuration, the building's adaptation potential, the purpose of the adaptation, economic factors, special needs, and pest control (Douglas 61-64).

Douglas summarizes the main stages of the process of getting to know the building:

- inception: the client's decision to adapt a building after all options have been considered;
- reconnaissance: part of the general physical description including the physical and spatial contexts of the building;
- feasibility: consideration of the economical, technical and legal implications of the proposed adaptation;
- desk-top survey: examination of oral and textual information about the building which should be performed before the site survey is undertaken to prepare the surveyor more fully for the site survey;
- on-site survey: inspection of external and exterior conditions and may also include a measured or dimensional survey of the property if as-built drawings are not available;
- structural appraisal: appraisal of the building by a qualified professional prior to adaptation that typically includes inspection of the substructure, walls, floors, roof structure, and chimneystacks;
- diagnostic survey: a strategy to determine the extent of any problems found in the structural appraisal by using specialized equipment and techniques;
- evaluation of options: consideration of condition of the building, spatial configuration, rental potential, and functional suitability are evaluated to determine the extent to which the building can be adapted; and
- proposals: after an adaptation strategy has been chosen design proposals of the scheme can be drawn up and estimated (67).

Douglas also offers a useful list of constraints that are found in his "Preliminary Considerations" chapter. These constraints include: spatial, technical, legal, financial, temporal, and environmental constraints, as well as client property requirements, physical site constraints, and value-added tax implications (Douglas 78-81).

The categories Douglas uses to describe the different ways to enlarge a building's volume add depth to his method. He defines three adaptations: lateral extensions which enlarge the building's volume horizontally (186); vertical extensions which addresses the

construction of a roof space adaptations or other forms of vertical extension (232); and structural alterations which includes any changes to the structural characteristics of a building such as removing a wall or adding structure (272). By going through this process before any adaptation work is undertaken assures that each factor has been thoroughly evaluated and the decision can be made on the building adaptation. If the building is suitable, an architectural proposal is produced.

Similar to Douglas's method, Watson identifies his own list of key issues to evaluate in determining whether a building should be adaptively reused. According to Watson, the task of the surveyor is to provide the client with a building that will meet their needs and keep the total project cost to a minimum (Watson 220). The surveyor should first establish the needs of the client, perform initial feasibility studies, and use the decision-making model²² (Watson 220).

If these steps are performed and an adaptation option is the result of the process, Watson provides a comprehensive list of key issues to be addressed for building adaption: building suitability, building structure, condition of building, aesthetics, project brief, sustainability, legal issues, and change of use (222). Watson's list of special considerations help in assessing a building's potential for adaptation once a site has been chosen because they have been organized and are asked after the initial feasibility study has been performed.

Reiner's book is dated but it offers a valuable section on locating a property for a specific use that was absent in the other literature that was reviewed. He advises that when the property is not known, the consultant must go through the additional steps of area and

²² See Watson pp. 221 for diagram of the decision-making model.

neighborhood surveys (Reiner 34). He further advises to make a survey of buildings in the appropriate locations in order to find the right building for the specific purpose (Reiner 34).

Reiner suggests a team consisting of a real estate consultant, architect-engineer, and construction contractor be formed to effectively locate a site for adaptation. The real estate consultant and broker adds knowledge about the market and prices and also movement and activity in the locations under consideration (Reiner 34). The architect, he suggests, must perform the aesthetic evaluation in which the building is examined “to make sure the size, shape and architecture (or external appearance) will be pleasing to the client... and also study the zoning and building codes” (Reiner 34). Reiner then explains that the construction contractor’s duties are to look over the shoulder of the architect as the design proceeds and seek structural and mechanical consulting to provide advice and budgetary estimates²³ (34).

Barrier Category	Factor	Reference
Geography		
Physical	Physical site constraints	(Douglas 78-81)
Human	Legal constraints, Change of use issues, Zoning codes	(Douglas 78-81), (Watson 222), (Reiner 34)
Economics		
Finance	Running (energy) costs, Economic feasibility, Source of finances, Value-added tax implications, Real-estate market	(Douglas 41), (Douglas 48), (Douglas 78-81), (Reiner 34)
Built Environment		
Site Infrastructure	Building adaptability, Physical feasibility, Functional feasibility, Existing construction type, Spatial constraints, Client property requirements, Adaptation type, Building condition, Aesthetics	(Douglas 41), (Douglas 48), (Douglas 58), (Douglas 78-81), (Watson 222), (Reiner 34)

Figure 12: Table of barriers to building adaptation and the associated factors to be considered in the planning process.

²³ In current architectural practice the architect would typically seek the services of structural and mechanical engineer consultants.

Summary

The UA community has done well in documenting observations on the success or failure of previous UA projects. Scholars seem to be particularly concerned with factors for total project integration into the surrounding urban ecosystems. Many of the reviewed methods for finding sites are particularly useful in developing an urban food project because they show how past projects have addressed land issues.

The controlled environment planners showed more concern for integrating the project into the surrounding urban market. The literature on planning for a greenhouse or CEA project revealed a more pragmatic approach to the site selection and design process which was heavily influenced by efficiency and cost factors. While there was a lack of literature on the important architectural factors to be considered when designing greenhouses specifically for urban locations, there is no lack of design literature on factors to consider in planning for a functional greenhouse.

The adaptive reuse literature was unique because it was concerned with issues in urbanism and cost. The factors to consider in selecting and designing a building for adaptation, however, are more focused on assessing the building. Few methods for site selection were found in the review, and the ones that were found were very general.

The literature review revealed a common general sequence of considerations in the planning of all the project types: 1) define the scope of the project; 2) select a site; and, 3) design the site. The considerations reviewed throughout provide a large pool of factors to analyze and organize in answering the research questions: which planning factors need to be considered in locating a site and deciding on a design for UA, greenhouse, and building adaptation projects? The literature also provided insight into which planning phase the

architect's role is most important in each of the disciplines; primarily in the site design phase of each. The following table categorizes important barriers and associated factors discussed in the literature review according to where they fit in the observed planning process sequence:

Phase	Barrier	Factor	Source(s)	Comment/ Observation
Project Scope				
	Geography	Land availability, Climate	UA, CEA	Defining the scope of the project is heavily influenced by local constraints and resources. Assessing these factors should result in an inventory of potential sites and a preliminary business strategy.
	Economics	Type of operation, Funding, Knowledge and skills, Grower expectations, Market demand, Availability of supplies and support services	UA, CEA, Adaptive Reuse	
	Built Environment	Client property requirements	Adaptive Reuse	
Site Selection				
	Geography	Land suitability, Land tenure, Land accessibility, Space for future expansion, Future land use predictions, Physical site constraints	UA, CEA, Adaptive Reuse	Factors considered in the site selection phase help determine which of the available sites is best suited for the proposed project. A preliminary analysis of the site's potential should be performed using factors from the disciplines in the literature review. This preliminary analysis should result in the selection of a potential site which can be further analyzed in the site design phase.
	Economics	Access to markets, Availability of labor, Pest pressure, Management residence, Road access, Property taxes, Real-estate market	UA, CEA, Adaptive Reuse	
	Built Environment	Water access, Existing structures, Utilities, Building adaptability, Physical feasibility, Building condition	UA, CEA, Adaptive Reuse	
Site Design				
	Geography	Orientation, Solar radiation, Wind patterns, Change of use issues	CEA, Adaptive Reuse	The site design phase should result in an informed decision on the feasibility of executing the project proposal using the chosen site. The constraints from the site and its surroundings inform a design that makes the highest and best use of the site. This critical phase of the design process requires the services of a professional architect/designer.
	Economics	Agricultural inputs, Vandalism, Vulnerability to storm damage, Type of production system, Economic feasibility	UA, CEA, Adaptive Reuse	
	Built Environment	Site plan layout, Facilities planning, Economic feasibility, Functional feasibility, Existing construction type, Change of use issues, Adaptation type, Aesthetics	CEA, Adaptive Reuse	

Figure 13: Table of reviewed barriers and factors for consideration. Each has been assigned to an appropriate planning phase. The bold type signifies which phase the architect's services were observed to be most needed based on the reviewed planning and design literature.

CHAPTER 3

CASE STUDIES

Introduction

The case studies serve primarily to illustrate a range of highly productive building integrated turnkey systems and to provide insight into the planning and design factors that are important for each type. The various production systems each have unique characteristics that act as constraints or opportunities for their application in the urban landscape. A review of the available literature on the proposed systems will be summarized and then evaluated for factors to be considered in planning and design. Factors that were found in the literature review were used to evaluate the cases. These factors included:

- 1) cost of system
- 2) agriculture production intensity
- 3) greenhouse structure requirements
- 4) greenhouse style
- 5) system spatial requirements

Additionally, observations of any unique factors were documented using written descriptions and illustrations as needed for each production system. Considerations related to the greenhouse production system were evaluated first because each system has significant formal differences and integration issues that affect the site selection and design of the BIA project. More importantly, assessing the greenhouse production system and reviewing the available literature on each case provided insight into which building types are best suited for the system. Once suitable building types are determined, UA factors found in the literature can be considered such as the land issues of availability, accessibility, and usability (suitability) as well as building adaptation

issues found in the literature such as construction type and aesthetics. These considerations help to inform the discussion about the potential impact of the BIA production system on the surrounding urban landscape.

Following the case studies, the collected data is then reviewed for patterns of important common factors as well as any significant differences found in considerations for their planning and design.

The case studies presented in this chapter include: the vertically integrated greenhouse (VIG), the rooftop greenhouse, and the mechanized greenhouse. Each case examined for this project is an example of a type of BIA system selected using the following criteria: it is available as a turnkey system; it is able to be retrofitted to the exterior of a building; it produces healthy food at a commercial scale by using extant food-production technologies; it uses all natural lighting – a true greenhouse system; it utilizes vacant vertical space; it is reasonably priced²⁴; and credible literature about the system was available. Using these criteria helped in choosing comparable systems for the study but the chosen cases only represent a small sampling of commercial-scale BIA project types currently being proposed in the United States.

Vertically Integrated Greenhouse

In 2007, the Vertically Integrated Greenhouse (VIG) was designed and developed by Kiss + Cathcart, BrightFarm Systems, and Arup (Kiss + Cathcart web). This

²⁴ Cost of the system is important because it helps the client choose a realistic BIA system. “Reasonably priced” will be defined as a commercial-scale turnkey production system that costs less than five million dollars. This sum is proposed to be realistic when compared to vertical farming proposals that are regularly estimated to be in excess of 20 million dollars to construct (Ensha web).

multidisciplinary team represented the fields of ecological engineering, plant science, architecture, and HVAC engineering (Caplow et al. 3).

The VIG is a façade-mounted system that uses patented vertical mechanized hydroponic technology (PCL) which is integrated into a double skin curtain wall system. It is for installation on new high-rise buildings and potentially as a retrofit on existing high-rise buildings with adequate southern exposure (Kiss + Cathcart web).

The system is intended to take advantage of the vertical surfaces on ever taller structures to bring nature to the built environment (Kiss + Cathcart web). The 2020 Tower designed by Kiss + Cathcart, Architects illustrates how the system is integrated into the south-facing wall as seen by the exterior and interior renderings below:

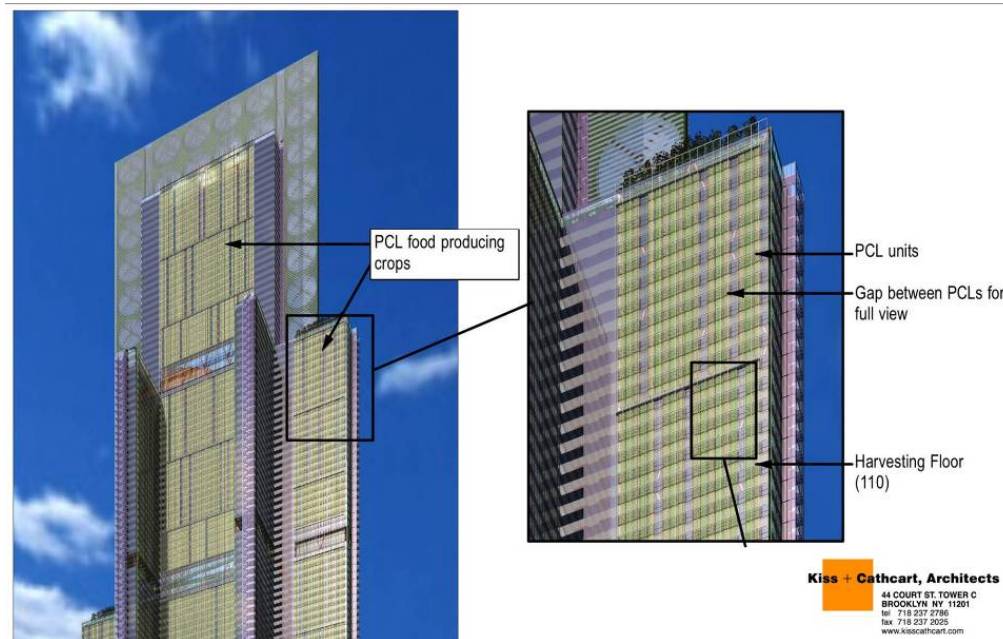


Figure 14: Rendering of VIG modeled on Kiss + Cathcart, Architects 2020 Tower (Caplow et al. 7).



Figure 15: Interior view of a VIG (Caplow et al. 3).

The VIG is unique because it is not only highly productive, it is also engineered to reduce building maintenance costs by providing shade, air treatment, and evaporative cooling to building occupants (Caplow et al. 3). The following section and detail diagrams illustrate how the VIG is integrated with building systems and controls daylight (Kiss + Cathcart web):

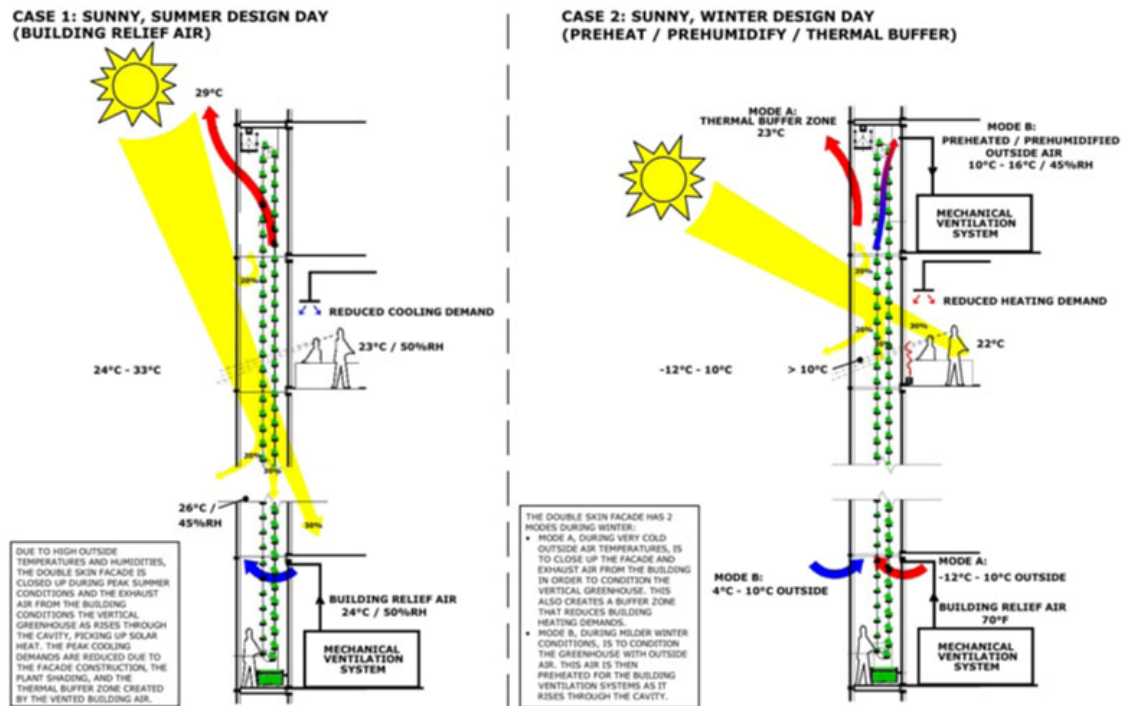


Figure 16: Arup's section diagrams showing the VIG's mechanized integration with building systems depending on the season and climate (Kiss + Cathcart web).

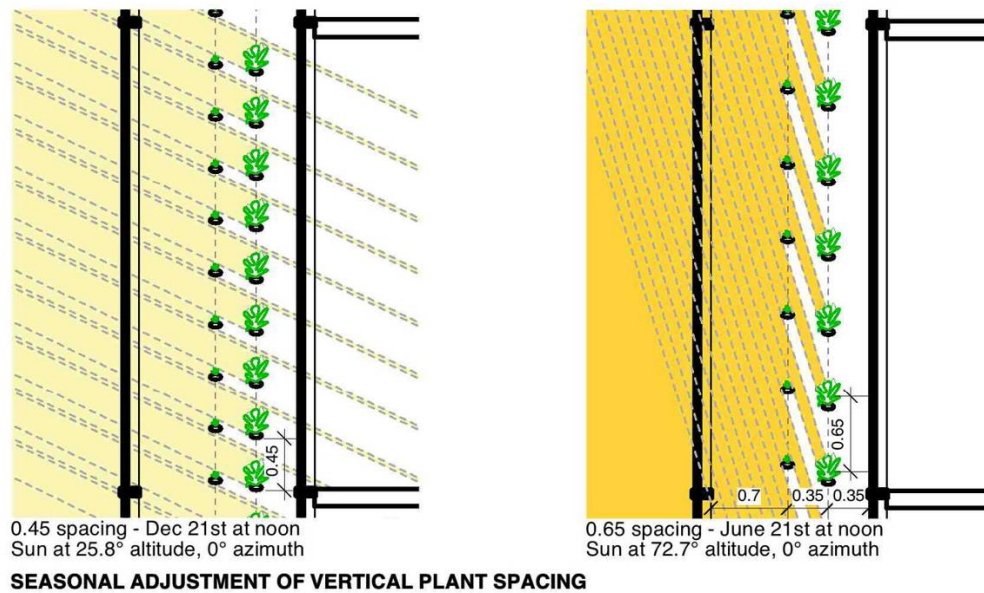


Figure 17: Section detail of daylight control using the VIG (Kiss + Cathcart web).

1) cost of system

\$2260 per m² is the estimated total capital cost which includes the double skin façade at \$2150 per m² and the PCL growing system at \$110 per m² (Caplow et al. 7).²⁵ Caplow et al. also provided an estimated operating cost of \$54 per vertical m² (7).

2) agriculture production intensity

Expected crop yields for a 50-story (125 m) VIG are 4,444 kg per m² of floor area per year.²⁶ The VIG system maximizes vertical growing area by using a vertical mechanized growing system but this system also limits the choice of crops to low-lying hydroponic crops²⁷.

3) greenhouse style

The VIG is housed in a double skin façade greenhouse style which can be considered an adaptation of the vertical mechanized greenhouse.²⁸

4) greenhouse structure requirements

A retrofitted VIG can be categorized as a structural alteration. It is a façade-mounted, modular, glazed double skin vertical curtain wall. Installation is for south-facing walls. Optimizing the structural design of the curtain wall needs to be completed (Caplow et al. 9). Structural engineering calculations are critical for the installation of the VIG and double skin curtain wall façade.

5) system spatial requirements

²⁵ This estimate is based on new construction double skinned façade costs in Europe (Caplow et al. 7).

²⁶ According to figures for the 2020 Tower, a 60 m wide by 1.5 m deep double skin façade system that rises 50 stories (125 m) is able to produce 400 metric tons (400,000 kg) of food per year using 135 PCL growing systems (Caplow et al. 8). In the same article, Caplow et al. provide an estimated production intensity of 37 kg per m² of vertical growing area for the VIG but no other details about this estimate were available so the figure could not be used (8).

²⁷ Dalrymple advises that the vertical mechanized greenhouse is most useful for shorter hydroponic crops such as lettuce and strawberries that use little vertical space, as opposed to tall climbing plants like tomato plant (37).

²⁸ The VIG is similar to the vertical mechanized greenhouses described by Dalrymple. These systems have been in use since 1924 (Dalrymple 39). This greenhouse style and construction for Dalrymple's example, however, was not discussed in the literature review because it was not widely cited as a common greenhouse type. Dalrymple's book was published in 1973 and even at this time the potential of growing crops vertically was understood; she suggests that, "the greater use of vertical space and mechanization will be an increasingly important matter in the future" (37).

A glazed curtain wall (a “double skin”) is located 1.5 m outside the southern building façade (Caplow et al. 4). This configuration creates a vertically continuous void for the PCL growing system. The modules are 2 m wide and can rise as high as 10 or 20 stories each (Caplow et al. 1 and Kiss + Cathcart web). Expansion of the greenhouse is mostly limited by available vertical area on the south-facing façade. The headhouse and working space for planting and harvesting at the bottom of each VIG module also require space planning as seen in figure 18:

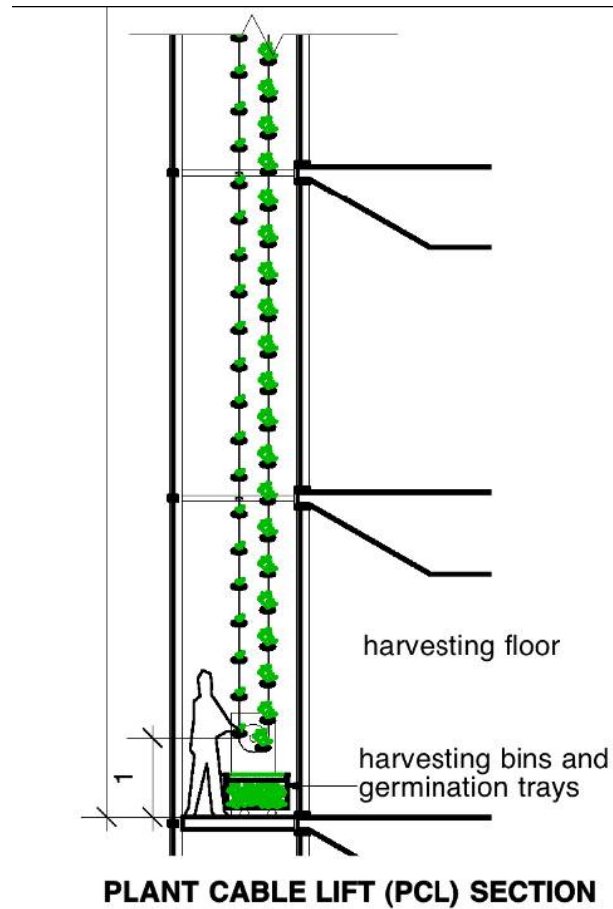


Figure 18: Section diagram of the VIG and working area at the base of each module (Caplow et al. 5).

Caplow et al. propose that the VIG is applicable to a broad range of buildings (6). The vertical emphasis and size of modular units, however, suggest that VIG would be best suited for a modern steel construction high rise building of 10 stories or more, such as an office building or a mixed-use project that may already have a curtain wall system. Even

though the VIG is described as lightweight, the structural loads created by the double skinned curtain wall system will require significant engineering of the lateral and vertical support structure. These building construction qualities may limit the building inventory of available spaces. It could be argued, however, that if vacant buildings are available for a VIG, the aesthetics could have a profound visual impact on the surrounding urban landscape. Therefore, a highly visible urban structure would be preferred.

Rooftop Greenhouse

Rooftop greenhouses are intensive hydroponic greenhouses installed on top of buildings. Installing greenhouses on roofs is also known as rooftop farming. There are a few young entrepreneurial companies offering these turnkey rooftop farms but Sky Vegetables was found to have the most resources available for review. Sky Vegetables was created by Keith Agoada and first introduced as the winner of the 2008 G. Steven Burrill business plan competition. The winning business plan proposed placing greenhouses on top of grocery stores.

The Sky Vegetables team “brings together experts in business development, construction, green building design and sustainable agriculture practices” (Sky Vegetables web). There is also a supporting Scientific Board of Advisors with “expertise in the fields of urban gardening, hydroponics, aquaculture, green building design and construction” (Sky Vegetables web). The team of advisors provides valuable insight into the technical, business and engineering aspects of sustainable rooftop agriculture (Sky Vegetables web).

This food production system exploits the often-overlooked potential of rooftop growing space by producing fresh crops “year round in a specially designed hydroponic

greenhouse array, tailored to fit rooftop real estate” (Sky Vegetables web). The system also utilizes video feeds for off-site crop monitoring. A schematic rendering of the Sky Vegetables rooftop hydroponic greenhouse and monitoring system is displayed in figure 19 (Sky Vegetables web):

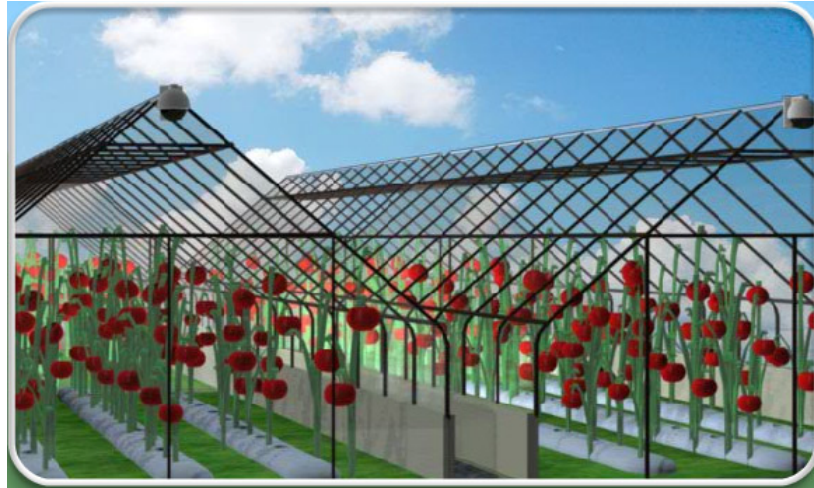


Figure 19: Conceptual rendering of the Sky Vegetables rooftop hydroponic greenhouse and video monitoring system (Sky Vegetables web).

According to Agoada, the Sky Vegetables system is Building-Integrated Sustainable Architecture (B-ISA). Their system integrates a number of sustainable building technologies into production agriculture and this makes Sky Vegetable’s B-ISA a unique case study selection. In the diagram below, the following systems are shown: greenhouse crop production, video monitoring, photovoltaics, vermin-composting, wind energy production, and rainwater collection (Sky Vegetables web).

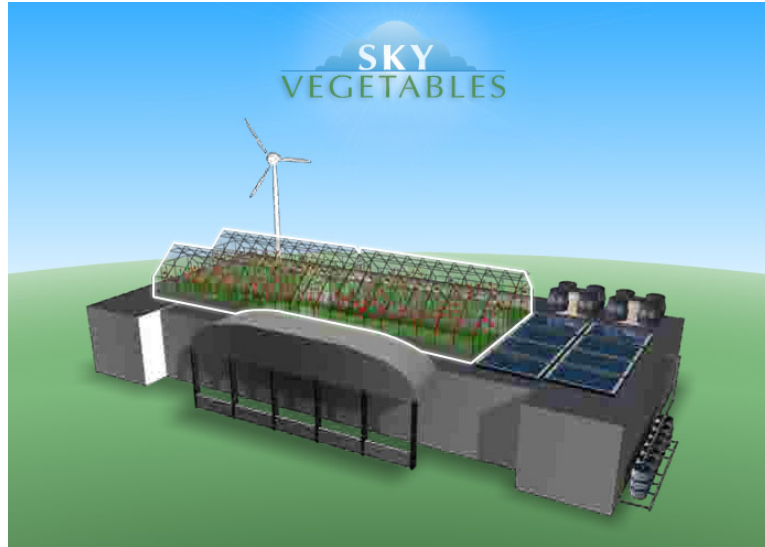


Figure 20: Conceptual rendering of the Sky Vegetables food production system. Fully-integrated sustainability features are incorporated. The faceless, gray building is effective in conveying the system's flexibility (Sky Vegetables web).

This business is currently still a proposal but has moved closer to being realized; they have received permission from the Brockton, Massachusetts planning department to locate their signature project above a vacant former shoe factory in a violent and underprivileged community. The proposed facility, seen in figure 21, will cover 440,000 square feet and produce 300-400 tons of food per year (Bolton web).



Figure 21: Conceptual rendering of the Sky Vegetables proposal for the first full-scale, commercial facility. The building is a vacant former shoe factory in Brockton, Massachusetts. The facility is estimated to produce up to 400 tons of food annually (Bolton web).

1) Cost of system

\$134.55 per m² is the estimated total capital cost for a commercial Sky Vegetables facility²⁹. No figures on the growing system cost or the operating cost were given.

2) agriculture production intensity

Expected crop yields using traditional hydroponic growing equipment are 8.8 kg per m² per year of facility roof area.³⁰ Images, such as figure 23, reveal the use of traditional hydroponic growing equipment in rows. The rooftop greenhouse has the benefit of requiring no real-estate outside of the building footprint.

3) greenhouse style

Attached even-span greenhouse.

4) greenhouse structure requirements

Rooftop greenhouses can be categorized as vertical extensions which typically have “greater constructional and structural implications than other forms of additions to buildings” (Douglas 232). The structural integrity of the existing roof is therefore an important consideration when choosing a building. The greenhouse structure is an even-span greenhouse for roof installation. The headhouse and the heavy hydroponic equipment it houses are installed on load-bearing exterior walls as seen in figure 25.

5) system spatial requirements

929 m² (10,000 ft²) is the minimum roof area required for a Sky Vegetables system. The system will also require uninterrupted roof space. While the crops are grown within the greenhouse in a specially designed array, the greenhouses seen in the available renderings appear to be proportional to typical stand-alone greenhouse construction types which range from 25 to 35 ft wide and 90 to 125 ft

²⁹ This sum is based on the proposed Brockton, Massachusetts facility which is estimated to cost \$5 million to complete (Bolton web).

³⁰ A conversion of lbs. to kg. and ft.² to m² was performed for comparison to yield data provided in the other cases. In Bolton’s article covering the first commercial-scale Sky Vegetables installation he suggests the facility will be approximately 440,000 ft.² and will produce up to 400 tons of food annually (Bolton web). Converted, the facility is 40,877.3 m² and produces up to 360,000 kg annually. It should be noted that this calculation was performed without knowing the percentage of the facility that is greenhouse space compared to space used by the integrated sustainable building systems.

long.³¹ Roof access and space for the integrated sustainable building systems also require spatial planning. The use of non-mechanized production systems also requires additional space for interior greenhouse pathways. Space is mostly limited by the available roof area.

The Sky Vegetables rooftop farming B-ISA model was originally intended for installation above grocery stores, but more recent comments by Agoada suggest that the system can be applied to a broader variety of underutilized buildings in the urban landscape:

We take underutilized space in urban areas and grow food there, creating green jobs, providing access to fresh produce, localizing the economy, and creating a better life by building communities through growing vegetables (qtd. in Makower web).

The rooftop and access construction needed, however, suggest that B-ISA is more limited. Structural engineering will be required to support the added weight of the greenhouse and building systems and therefore an overbuilt existing structure would be preferred. An example of this building type is the vacant industrial building Sky Vegetables chose for the Brockton, Massachusetts installation. Another option would be to find a more widely available building that is affordable enough to offset the additional construction costs of rooftop farming.

The visual impact of the Sky Vegetables rooftop farm will be determined by parapet heights and approaching views into the site. Taking these factors into consideration will help to make the greenhouse more noticeable, otherwise the rooftop farm may only be seen by those that have access and have little to no visual impact on the surrounding urban landscape - a wasted opportunity.

³¹ See Hochmuth et al. HS776.

Mechanized Greenhouse

Mechanized greenhouses use conveyor technologies inside of controlled environments. There are many types of mechanized greenhouse growing systems but the company Valcent Products Inc. offers the patented Verticrop turnkey system which is described as a High Intensity Vertical Growing System (HDVGS). Valcent Products Inc. is headquartered in Vancouver, British Columbia with offices in the U.K. The company also consists of Valcent Products (eu) Limited, which is a European subsidiary responsible for sales and marketing. The company is well-recognized as a leader in sustainable agriculture production with endorsements from members of the Kennedy family and accolades from Time Magazine as being one of the best inventions of the year (Valcent web).

The HDVGS is an especially intensive production system to be installed in controlled environments such as greenhouses, poly tunnels, or warehouses (Valcent products eu ltd. 3). The system grows plants “in a vertical plane in specially designed trays suspended from an overhead track. This allows the trays to rotate on a closed loop conveyor and in the process pass through a feeding station which provides water and nutrients” (Valcent products eu ltd. 3). The HDVGS maximizes its use of the total growing area within standard greenhouse structures by stacking vegetation vertically as seen in figure 22. The significance of this system in making use of underutilized greenhouse growing area is illustrated in the comparison chart figure 23. The conveyor system also helps increase production intensity by evenly distributing sunlight and increasing airflow for the plants.



Figure 22: This image shows Valcent's patented HDVGS, Verticrop (Valcent web).

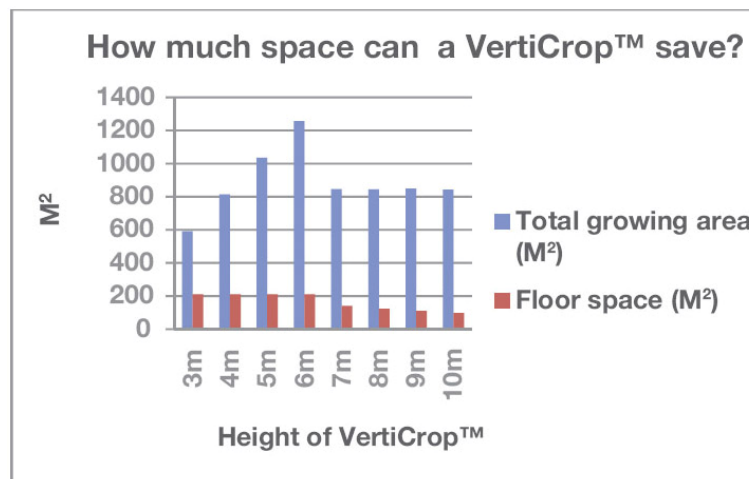


Figure 23: This table shows potential growing area for different HDVGS models (Valcent products eu ltd. 10).

Verticrop is able to be installed in a variety of controlled environments; Valcent is even developing a model to be housed completely inside of adapted industrial buildings and rely entirely artificial lighting (Valcent products eu ltd. 14). For the purpose of this study, however, only the basic greenhouse HDVGS application will be considered because it would be able to utilize the abundant sunshine in Las Vegas. The system reviewed in this study is based on Valcent's descriptions of its basic Verticrop model and analysis of limited

photographic documentation of the greenhouse style and structure used in the prototype at Paignton Zoo and other commercial scale testing facilities.

HDVGS is unique because of its high productivity, validity, and flexibility. This mechanized system also shares an important characteristic with VIG: the fact that both reduce labor requirements that are needed in typical greenhouse layouts because the conveyor allows laborers to seed, harvest, and monitor crops from a single set station.

1) Cost of system

\$1,107 per m² is the estimated total capital cost for the HDVGS.³² No figures for the operating cost were given.

2) agriculture production intensity

Expected crop yields for a six meter tall HDVGS are 500 kg per m² of floor area per year.³³ This high yield is achieved because the system takes advantage of the vertical growing space with densely-grown crops. Like the VIG this system is limited to low-lying crops as shown in figure 24:

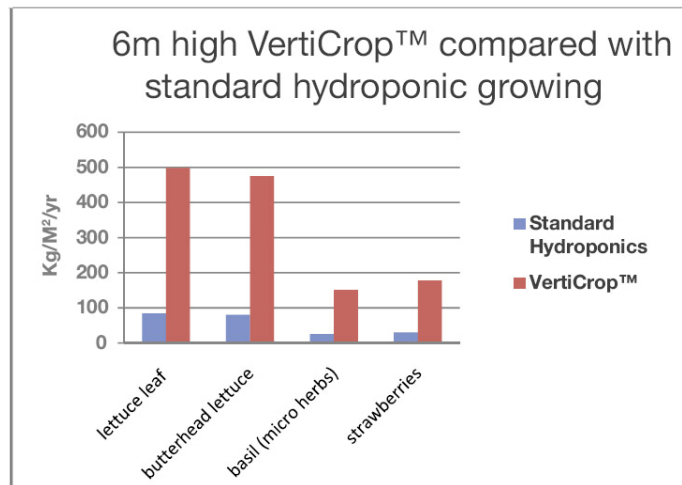


Figure 24: This table shows data for annual crop production comparisons, notice all of the types are low-lying crops (Valcent products eu ltd. 11).

³² The sum is based on the basic Verticrop system costing \$566,000 (Valcent Products Inc. 5).

³³ A conversion of lbs. to kg. and ft.² to m² was performed for comparison to yield data provided in the other cases. The basic facility is 5,500 ft²; if converted, the facility is 511 m² and produces up to 500,000 kg of leaf lettuce annually (see figure 28).

3) greenhouse style

Attached even-span greenhouse. Aesthetics and massing are particularly important in choosing the greenhouse style for lateral extensions³⁴ because this greenhouse attachment should integrate with its surroundings as it is highly visible.

4) greenhouse structure requirements

The attached greenhouse can be categorized as lateral extensions (Douglas 186). Photographs suggest the greenhouse structure is an even-span greenhouse. Existing site surface conditions are a concern because the greenhouse floor will need to be smooth and gently sloped for drainage. An extra or separate structure in addition to the greenhouse framing will be needed to support the HDVGS. A connection to the building will need to be structurally supported and weatherproof.



Long shot of plants being planted out.
Note irrigation/fertilization area on left

Figure 25: Empty HDVGS which reveals a Quonset greenhouse on a rigid frame (Valcent web). The use of supporting side walls allows maximum space and air circulation.

5) system spatial requirements

The basic system floor area is 511 m² (5,500 ft²) (Valcent Products Inc. 1). The floor will require an uninterrupted surface so nothing interferes with the moving

³⁴ See Douglas p. 198-204 for discussion on lateral extension volume additions.

conveyor panels. Nutrient feeding station and seed and harvest stations also need to be planned for. The greenhouse connection to the building is a critical interface and the space that is created may be integrated with the headhouse. Applications of the HDVGS are limited from expanding by a one-story height limitation and the available horizontal space on the site for typical 25-35 ft wide and 90-120 ft long greenhouse modules.

The Verticrop HDVGS is unique because it is an example of a stand-alone system, which makes its aesthetic integration into the existing building potentially more difficult. Covering materials may be important if the greenhouse is highly visible and this will affect the greenhouse construction type. The greenhouse construction will affect massing and proportions of the greenhouse which is very important in integrating the structure into the existing building and the surrounding urban landscape. In terms of structural issues to be considered for integrating the greenhouse, this is the least invasive of the three cases and will help to make the inventory of available building types larger and help to leave behind a less altered building if the greenhouse is ever removed. The buildings will, however, need to have sufficient available horizontal space for the greenhouse and future expansion, unlike the other cases.

An urban building that is well-suited for an attached even-span greenhouse housing a HDVGS is a vacant big box retail store. The vacant big box is not considered aesthetically relevant architecture therefore a simple greenhouse may be a welcome aesthetic addition. The exterior walls of big boxes are generally taller than six meters, they are not structurally overbuilt, they have large flat parking lots with existing drainage, and they are increasingly available and affordable. All of these qualities help make it a suitable building type for an attached HDVGS and greenhouse.

Summary

The three cases represent unique BIA solutions to choose from in order to integrate agriculture production into an urban site. As demonstrated by the cases, commercial agricultural production in BIA projects can create an architectural statement on buildings, it can be hidden out of site on the roof, or it can be housed in a simple building addition. The different characteristics of the three systems allow a wider pool of available urban spaces to be considered for agriculture production, or if the property is already known there is greater flexibility in choosing the most appropriate system to respond to the site's opportunities and constraints. The different characteristics of each system also help to define the factors that are most important when choosing a particular BIA system.

An important observation is that each BIA facility was able to produce crops at a high intensity – more than 350,000 kg per year – but the economic, structural, and spatial requirements to do so were drastically different. For example, the rooftop greenhouse is the least expensive system per square meter and it can be installed so as not to have an impact on the exterior aesthetics of a building, but it also requires the largest floor plan area, is the least productive per square meter, and may require expensive structural support for the added roof load. The mechanized systems that utilize vertical space such as the VIG and HDVGS had much smaller footprints than needed by the traditional greenhouse structure used in rooftop farming and were much more productive per square meter, but they were also more expensive to install per square meter than the rooftop farm and had much larger aesthetic impacts on the existing building.

The studies also revealed that each system has unique architectural opportunities and constraints for their integration into existing building types. It was found that the VIG is

best suited for a tall and highly visible building type such as an office building or possibly a mixed use project. The rooftop farm is best suited for overbuilt structures that do not allow for alterations to the exterior aesthetics such as a historically-significant industrial building. The HDVG is best suited for buildings that are not structurally able to support façade or roof applications and buildings that are on sites with large expanses of flat surface such as a retail building with a parking lot.

Comparison of the case studies can be illustrated in simple graphic form using two of the most important BIA planning factors found during the analysis of the case studies: the cost of initial investment and the flexibility of design requirements to integrate the greenhouse structure into an existing site.

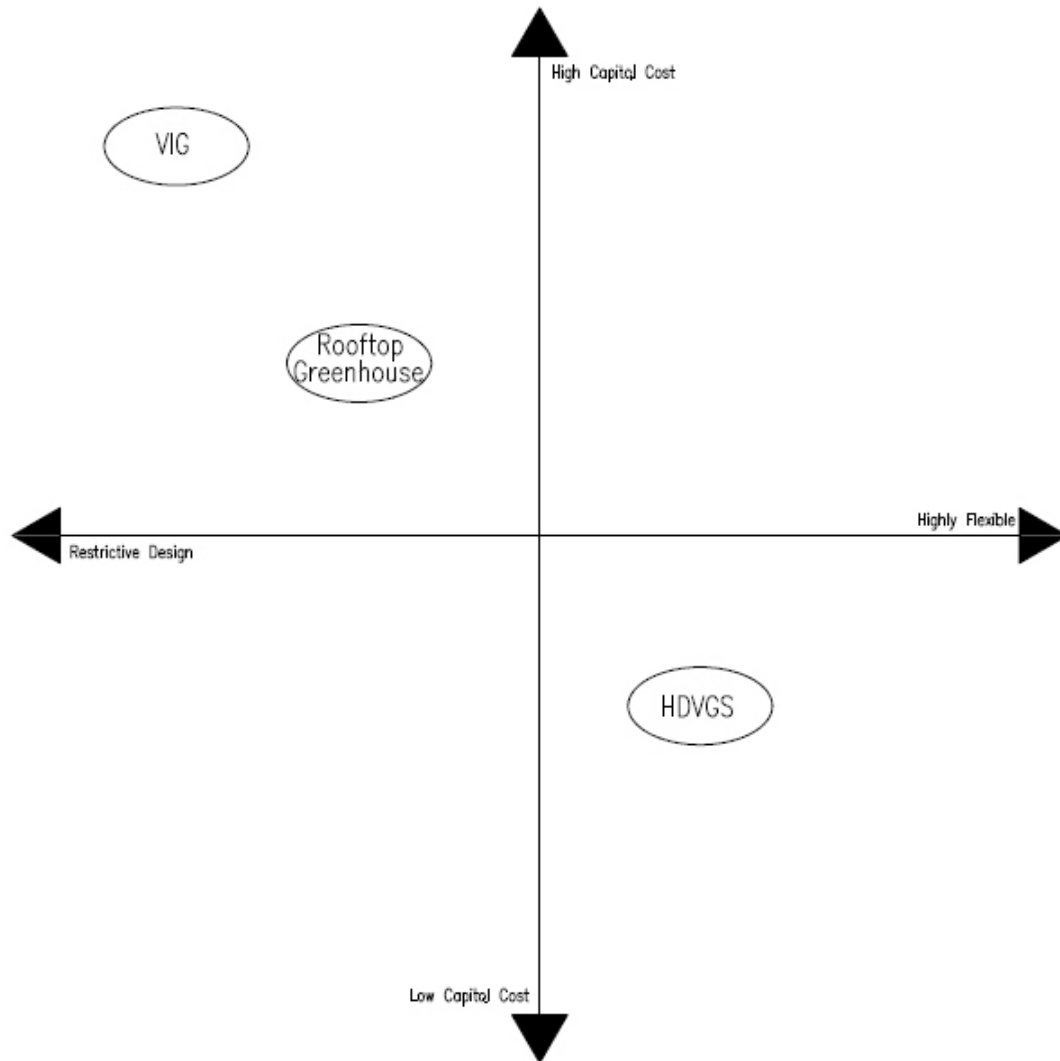


Figure 26: Comparison map of reviewed case studies using design flexibility (x) and capital cost (y) as the factors

The comparison map illustrates the idea that each system responds differently when these important planning factors are considered. If a VIG or Rooftop Greenhouse system is being proposed for a project, the initial cost and design requirement restrictions are critical factors in the planning process because they will have a significant impact on the project budget, site selection, and design program. If an HDVGS is planned, the lower capital

costs allow for more flexibility in the planning phases and especially the design phase to achieve a well-integrated and functional BIA facility.

It was also observed that the information from comparing the BIA system options is useful at different phases depending on the land situation. Two scenarios are: 1) a particular BIA production system is chosen based on a critical long-term planning factor (cost) and system design requirements and this choice helps guide the search for a suitable site; or 2) if the site is already selected, the requirements for each BIA production system can be considered to help determine the most suitable system for the given site. At whichever phase the BIA system is chosen in the planning process, whether in the project scope phase or the site selection phase, the programmatic and project budget information from this decision are critical factors to consider in the design phase for a successful BIA facility.

CHAPTER 4

PLANNING STRATEGY FOR BIA IN LAS VEGAS

Introduction

In this chapter, a strategy is developed for the BIA planning process. The developed strategy provides a sequence of factors based on analysis of the planning factors discussed in the previous chapters. The most important factors for BIA planning are chosen, combined, and organized. The result of these efforts is a planning strategy that can be used as a tool to help ensure the success and feasibility of a BIA proposal, and in addition, guide the architect's efforts to the stages and decisions in which they are most able to help facilitate BIA's integration into the urban landscape.

After the strategy is outlined and explained, it is then tested by applying the planning strategy to a proposed Las Vegas site. Applying the BIA planning strategy to a local site helps to understand the potential for this type of project in Las Vegas, define the most critical factors in planning for a Las Vegas BIA project, and also determine the usefulness of the devised strategy to the architect/designer. Maybe more importantly, this test demonstrates how the strategy can be used.

Identifying & Organizing Planning Factors for BIA

The reviewed literature provides information on planning factors for UA, CEA food production, and adaptive reuse of existing building stock. Each field provided unique and/or overlapping factors to consider in the different stages of their planning processes. It was also found that each field shared some common barriers and a similar sequence of planning phases in the general order of 1) long-term planning, 2) site selection and, 3) site

design. Creating the outlines of material discussed in the literature review helped in discovering the common planning phases and overlapping barriers. These commonalities were found to be useful in organizing the planning factors, so the decision was made to adapt this format for the proposed BIA planning process. Collectively, the pool of factors extracted from the literature review represent a majority of factors that are considered in planning for a successful BIA project, but some were unique to BIA such as the system design requirements described in the case study analysis.

While the reviewed material influenced the decisions on what the major barriers, factors, and decision-making sequences are for planning a successful BIA project, it was also found that the architect's role is limited to the design phase of the reviewed planning processes. This research attempts to better understand the role of the architect in facilitating this new, healthy, technology into the urban landscape. In addition to combining, organizing, and adding to the list of reviewed factors used to develop a unique set of BIA planning factors, this BIA strategy is also a useful tool for the architect.

In making the strategy for an architect's use, it was recognized that the architect may not need to be directly involved in the project scope and site selection phases of BIA planning. These are the preliminary phases to be considered before the architect's design phase. Yet, the factors considered and decisions made in these phases of the project are important information for the architect prior to initiating the design phase. One reason is that architects are curious by nature and absorb all possible information concerning a project because it will all inform the design solution. Another, more pragmatic reason: the architect should be aware of what has been verified and evaluated in the two preliminary phases is because it gives them an idea of the feasibility of the BIA proposal and if it is at a

stage where architectural services are needed and justified. If the necessary factors have not been addressed to make the proposal feasible, the architect has a list of the project scope and site selection factors on hand for the client to consider before architectural services are rendered.

The decision-making strategy was established as a set of three consecutive phases in which common barriers to integrating food production are addressed by considering BIA planning factors in each project phase. Once the factors have been considered and the barrier is sufficiently addressed, the planner moves on to the next barrier and associated factor. A table outlining the steps in the devised BIA planning strategy is shown in figure 27.

Phase	Barrier	Factor
1) Project Scope / Programming	a. Geography	Site availability
	b. Economics	Production system selection
	c. Built Environment	Client property needs
2) Site Selection	a. Geography	Building type legal suitability
	b. Economics	Building location characteristics
	c. Built Environment	Existing site infrastructure adaptability
3) Site Design	a. Geography	Production system requirements
	b. Economics	Production & distribution potential
	c. Built Environment	Technical issues & aesthetic impact

Figure 27: Table of reviewed barriers and factors for consideration. Each has been assigned to an appropriate planning phase for BIA planning strategy.

Defining and Applying the BIA Planning Strategy in Las Vegas

The barriers to BIA are categorized in each phase as geography, economics, and the built environment. Geographic barriers include both physical geography (such as topography) and human geography (such as land use policy). The economic barriers are concerned with any issues in the production, distribution, and consumption of food produced by the BIA system. The built environment barriers are issues caused by existing structures on the site and its surrounding infrastructure. Each phase of the planning process deals with these three issues.

The planning factors are basic considerations that help to address the common barriers. The factors are organized in a logical sequence to evaluate the feasibility of the BIA proposal in each phase of the decision-making sequence ensure a successful BIA project. The planning factors to be considered in the strategy are defined in the following pages so the client and architect can verify that each barrier has been appropriately responded to in each phase of the project.

Even though the architect is not needed until the project design phase, a more active role as a consultant to the client is proposed in the project scope and site selection planning phases. This role is reflected in the definitions and examples in the following pages by providing a more in-depth description of the factors thought to be most important to the architect/designer – especially in the design phase.

The result of going through the developed planning strategy is a body of data including a design proposal that informs the feasibility of the proposed BIA project. Major opportunities and constraints for the proposal are identified by using the devised strategy.

Further the outline is useful as a checklist for the architect and client to reference when deciding if the design proposal is worth investigating further after each phase.

1) Project Scope Phase

In the first phase of the strategy, defining the project scope, the client is primarily responsible for collecting the information used to address the planning factors. By going through this process, the client will have ensured that the following basic information concerning the BIA design proposal has been planned for: site availability, production system type, and client property needs. These basic issues need to be addressed to verify that the proposal is feasible and allow the planning process to go forward into the site selection phase or the site design phase.

The architect will be responsible for knowing the decisions that were made and verifying that each of the barriers has been addressed by the client, but the architect's role in making decisions about the scope of the BIA project is minimal beyond consulting on an as-needed basis.

1a. Availability –

The first factor to consider in the project scope phase is site availability. The client may already have a site for adaptation, but if the site is not known, a community assessment should be performed. The assessment should help compile an inventory of available properties for BIA adaptation based on criteria from the client's business strategy and the opportunities and constraints found in the community. For BIA projects, the most likely available properties are vacant commercial buildings.

1b. Production system selection –

The type of production system to be used should be determined early in the planning process. At the very least, the client should have an understanding of the options for turnkey BIA systems. These packages should be considered by the client to help minimize errors in estimated projections and costs in the business plan. The packages are widely available and can be customized to include: protected structure, hydroponic and support systems, consulting, and marketing agreements (Shrethsa and Dunn 4).

The type of BIA production system that is chosen can be used as a factor to consider in selecting a site, or if the site has already been selected, the most appropriate BIA system can be chosen to make the best use of the existing site. Either way this information is used, at this stage of the planning process the client should have an idea about economic expectations for the project. This information also gives the architect an idea of the structure(s) that will need to be integrated into the site.

1c. Client Property Needs

The client should be able to discuss any special design factors beyond the BIA theme that need to be incorporated into the project. The following are some examples of questions the client could expect: is the project planned as a wholesale or retail operation? Is this project intended for agricultural tourism? Should the property function as a community center? Is there an objective related to sustainability? Is there a concern with security?

The objective of evaluating client property needs is for the architect/designer to have a general idea of program requirements and goals for the project.

2) Site Selection Phase

The site selection phase can be used in two ways in BIA planning: the proposed project design requirements defined in the previous phase can be used to assess the inventory of available sites developed in the project scope phase and determine which is most suitable for integrating BIA production, or if the site has already been provided by the client, the list of factors can be used as a reference for testing the feasibility of the proposed site. When the site is not known, the factors presented in this phase can be used as criteria to be applied to the inventory of available sites and used as sieves in a similar method to that proposed by Bhattacharya (59). Applying the criteria systematically limits the inventory of available sites to the most suitable site so it can be evaluated in the site design phase.

Much like the factors considered in the project scope phase, the factors presented in the site selection are intended for the client to consider. In general, the site selection factors address issues that are beyond the scope of architect's professional expertise but the designer should be available for consultation.

2a. Building type legal suitability –

One of the most important issues found throughout the review was the issue of land tenure. A higher initial investment to integrate BIA production technologies should be expected and this makes land tenure a critical factor for choosing a site. Local zoning codes should also be considered to verify that the production and distribution of crops on the sites is legal. Any of the available properties that do not offer land tenure or are not zoned for commercial crop production should be removed from the inventory.

2b. Site location –

The surrounding urban landscape provides opportunities and constraints to a successful BIA project. The information developed from defining the project scope helps inform a more in-depth study of the site location. The study can include assessment of the consumer market, the real-estate market, site accessibility, property taxes, surrounding buildings, and even future land use predictions. These factors inform criteria that can be applied to the list of remaining sites. The criteria informed by these considering these factors should be quantifiable so the inventory of remaining sites is easier to evaluate. A real-estate broker or developer can help with developing the location study and the architect should perform an initial investigation of any local design standards or guidelines for adaptation projects at the site locations.

The location criteria developed in the study can be applied to the inventory of available and legal sites and used to discard any sites that are not suitable. The result of this process should be a short list of available, legal, and well-located sites.

2c. Existing infrastructure adaptability –

The list of remaining potential sites should be evaluated by an architect/designer to determine their adaptability potential. Any existing structures and infrastructure on the sites should be quickly evaluated as to their suitability for integrating the BIA project proposal. Factors that help determine the adaptability potential include: demolition needs, utility and water access, building construction type, existing commercial infrastructure, flexibility of interior space, and flexibility of site space. Considering these factors gives the

architect/designer an idea of the obvious improvements needed to integrate the BIA facility.

A scale should be developed by the client to rank the remaining sites according to which require the least amount of preparation for the BIA adaptation. This assessment helps identify capital construction costs that affect the feasibility of the project as well as any substantial changes to the existing structure that may decrease its future value if the BIA facility vacates the site.

3) Site Design Phase

Once the project has addressed the barriers in the previous two phases and a suitable site has been chosen to study for the design phase, the architect/designer has the task of further evaluating the site, collecting information in more detail and providing a rough design study of the proposed BIA adaptation. The architect is able to illustrate the description of how the BIA system will be integrated into the existing site. The architect produces drawings for use as a conceptual tool for evaluating and explaining the feasibility of the proposed BIA adaptation. This phase demonstrates the importance of the architect's role in providing a level of precision that helps to determine feasibility. After the factors have been considered in this phase, a decision can be made with the client to go forward or move on to analyze other BIA adaptation proposals.

For the purposes of this thesis, a site in Las Vegas has been chosen for the site design phase. Though the site has many qualities that make it a valid selection for studying BIA integration, the site was chosen based on the amount of information available about the building and not from extensive research into the best sites available in Las Vegas.

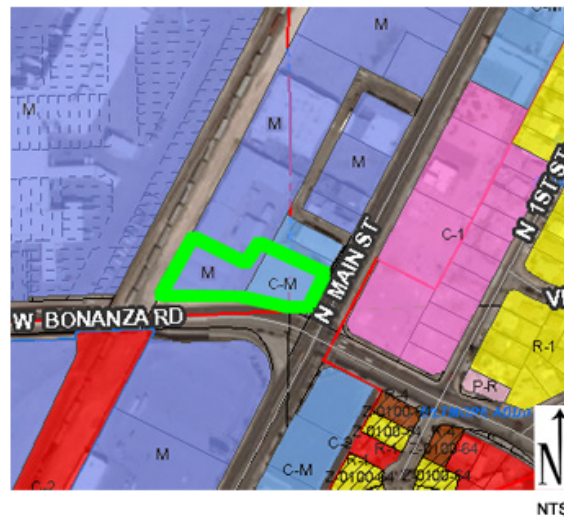
The site is presented as if a client has already chosen an existing vacant site to adapt for BIA activities. It is assumed that the selection of this site considered the factors in the previous phases and that it has shown to be promising for integrating BIA. The client would like to integrate a turnkey BIA production system similar to one of the systems discussed in the reviewed case studies for retail operation. These are appropriate assumptions for this study because it is intended to be an architectural study on how to integrate BIA into the built environment. If data from the Project Scope / Programming and Site Design phases is assumed, it allows this thesis to go into a more in-depth discussion of the design phase which is where the architect's role is most valuable. To be more clear on how the logic in the entire BIA planning strategy is applied, however, the following summary and Figures (28-33) illustrate the type of data that can be expected as a result of going through the first two phases of the proposed strategy and show how the logic is applied to the chosen Las Vegas site:

The chosen site is a corner lot zoned for industrial use and the owner is willing to negotiate lease tenure. The site houses a vacant 18,000 square foot commercial warehouse built in 1955 and 26,500 square feet of blacktop surface including a small loading ramp. The site is surrounded by Bonanza Road to the south, train tracks to the west, commercial buildings to the north and east of the site including an antique shop, and Main Street to the east. It is accessed by a shared road off of Main Street just north of the antique shop. The site is highlighted below:



Site

Figure 28: Map of Las Vegas, Nevada identifying site location. Scale: not to scale



- SITE BOUNDARY
- C-1
LIMITED COMMERCIAL
- C-2
GENERAL COMMERCIAL
- M / C-M
INDUSTRIAL / COMMERCIAL-INDUSTRIAL
- RESIDENTIAL

Figure 29: Vicinity map showing planned zoning for the site and surrounding parcels. Scale: not to scale

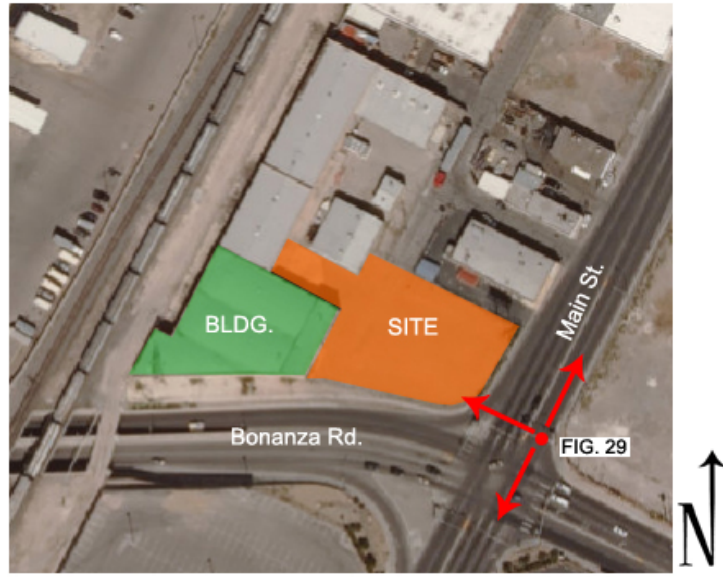


Figure 30: Site plan to be studied in the design phase; views for figure 29 are shown in red arrows.
Scale: not to scale. Location: 601 North Main Street Las Vegas, Nevada.



Figure 31: Panorama documenting north, west, and south views of site and its surroundings. The existing building onsite is highlighted in green.



Figure 32: 3D rendering perspective of existing conditions looking into site from Bonanza Road and North Main Street intersection.



Figure 33: View of east façade and interiors of existing structure.

3a. Production system requirements –

The factors to be considered for the system requirements are concerned with any geographic features that affect the BIA production system's ability to function correctly. Some of these factors include access to sunlight (orientation and shading structures), wind patterns, site topography, drainage, and available land for future expansion. Other factors may include any special requirements specified for the turnkey packages such as minimum footprints for the production system, headhouse, or enclosure structure. A useful drawing for documenting and assessing the production system requirements affected by geographic barriers is a site plan as seen in figure 34:

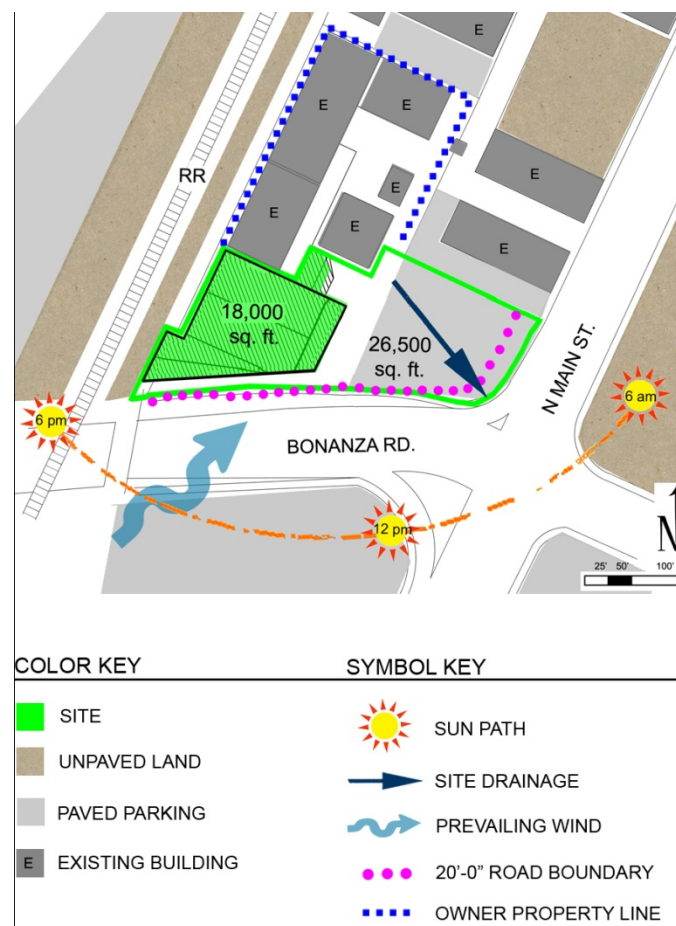


Figure 34: Site plan showing geographic barriers.

It was found that there are no natural or built shading structures surrounding the site to the south. It is important to note, however, that the undeveloped lots to the south, southeast, and east are vulnerable to future development which may block the site's access to sunlight. While the lack of developed land surrounding the site is ideal for sunlight access, it provides little protection from the prevailing winds from the southwest. The site is completely exposed to prevailing winds and will require a natural or built barrier for greenhouse protection and climate control. The existing building stock that surrounds the site is located to the north and north-east. These structures will not affect greenhouse performance and those within the owner's parcel boundary are available space for future expansion.

The site's topography is 26,500 square feet of flat impervious surface that is slightly sloped to drain toward the intersection of Bonanza Road and Main Street. The paved surface is available space for the greenhouse enclosure structure used to house the HDVGS. The 20 foot road boundary used as a periphery boundary for the greenhouse only occupies approximately 1,900 square feet of the paved area, which leaves 24,600 square feet of available space. This is more than enough area for the minimum HDVGS enclosure footprints. Similarly, the rooftop is approximately 18,000 square feet of vacant space which is available for rooftop greenhouse use. This exceeds the 10,000 square foot minimum specified by Sky Vegetables. The south-facing wall measures 185 feet long (56 meters) which is similar to the footprint of the VIG proposed for the 2020 Tower but the existing structure is only a single story building which does not allow for a tall VIG system.

The site's human and physical geographic barriers do not appear to sieve out any of the three turnkey BIA system choices based on consideration of the selected factors. At this

stage of evaluation in the site design phase all three systems should still be considered for project integration.

3b. Production and distribution potential –

Considering the factors involved in the production and distribution potential of the site requires an analysis of the existing structure(s) and the site infrastructure. Space should be allotted for the maximum growing area; headhouse; harvesting area; packing facility; storage; shipping and receiving areas; and delivery vehicle access. The layout should be conducive to the flow of materials and if the site is intended for retail, the layout should also account for customer access, parking, and retail space (Kessler 4). Other factors to be considered are security needs and vulnerability to storm damage.

A site plan can be used for documenting site access and existing infrastructure, as seen in figure 35.

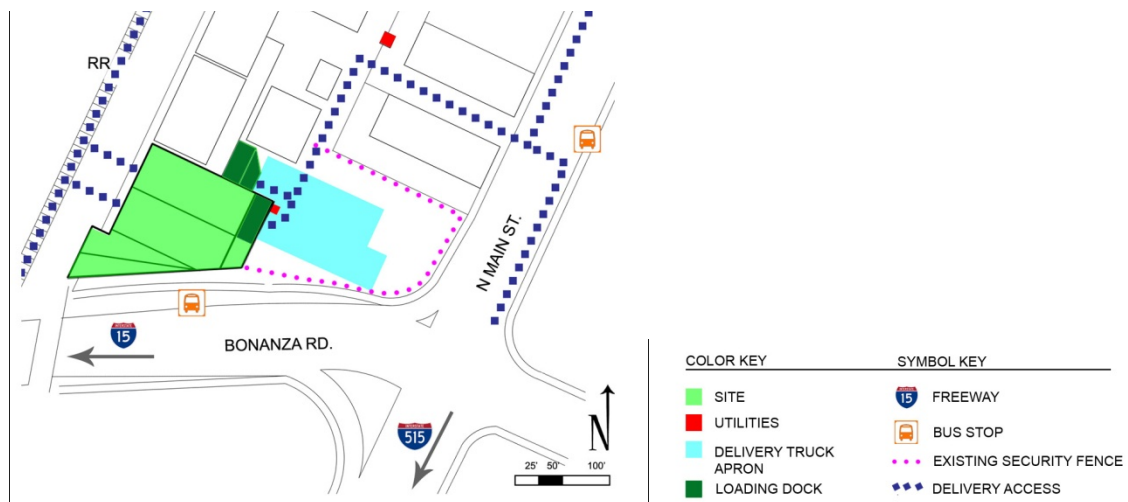


Figure 35: Site analysis documenting existing infrastructure and site access. Delivery trucks and customer vehicles access the site by a shared alley road off of Main

Street. If all of the existing shipping and receiving areas are used on the site, the delivery vehicles require approximately 11,500 square feet of maneuvering area³⁵. It was also observed that the site is located in an accessible area of Las Vegas due to its proximity to major interstates, rail road, and bus routes.

Next, the maximum growing area the site can support should be evaluated. If the type of turnkey production system to be used is undecided, as in the Las Vegas example, determining the maximum available space for producing crops provides insight into which system is best suited for the site. A spatial analysis for integrating a VIG system is illustrated in elevation in figure 36.

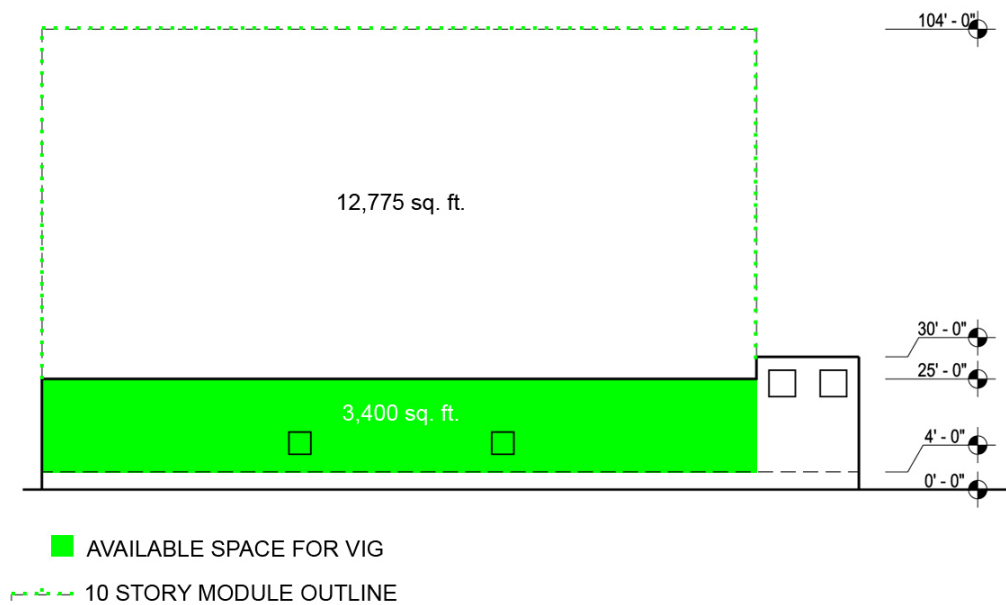


Figure 36: South façade elevation showing the available space for integrating the VIG in comparison to the scale discussed in the literature.

³⁵ This calculation is based on accommodation of 65 foot long delivery trucks. The general rule is to provide two times the truck length for area in front of the loading docks (Blue Giant web).

This diagram reveals that the available south wall space on the Las Vegas site is small compared to the space needed for the VIG modules discussed in the literature. The VIG is available in modules of up to 10 and 20 stories tall. The 2020 Tower used VIG modules at this scale to build a 60 meter tall façade. There was little mention of using the VIG system at smaller scales and this suggests that the available surface area on the south façade of the Las Vegas site (3,400 square feet) is not large enough for the VIG to function at a highly productive level. The VIG adaptation should be dismissed as an option at this point due to the lack of available space.

There is enough space, however, to house the minimum footprint requirements for the rooftop greenhouse and enclosure for the HDVGS as seen in figures 36 and 37. Once it has been established that there is enough space for a productive system, the other factors to consider in production and distribution should be evaluated. Spatial layouts of the program requirements should be diagrammed as well as the flow of customers and materials for the two remaining options. This process is demonstrated in figures 37 & 38:

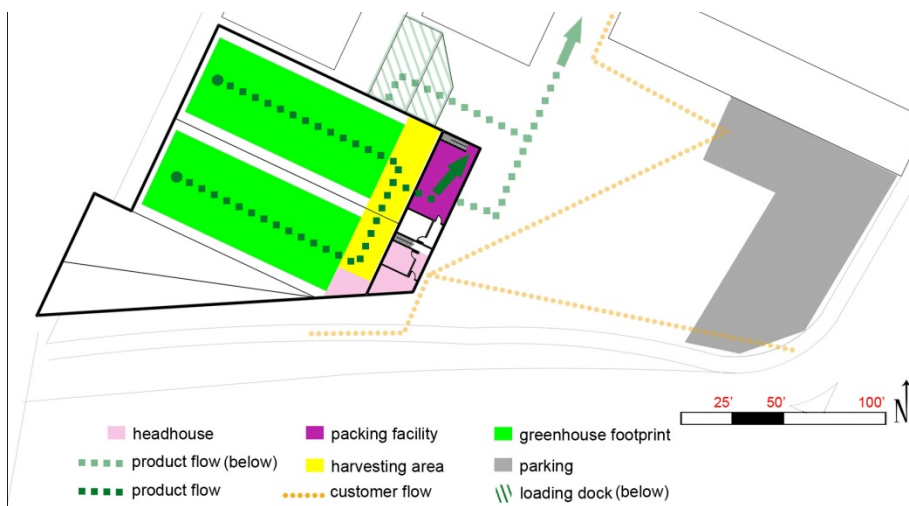


Figure 37: Layout proposal for the rooftop greenhouse showing flow of materials for retail distribution.

Figure 37 shows the rooftop can fit approximately 8,000 square feet of traditional greenhouse space which can be accessed from the second floor. The second floor also has room to house the harvest area, headhouse, and packing facilities. It is connected only by stairs to the ground floor so this floor would not be accessible to the public without some major renovations and additions required by the local building code.

Having the harvesting and packing facilities on the second floor allows the retail, warehouse, and shipping/receiving spaces to occupy the ground floor of the building which will require little adaptation beyond minor cosmetic alterations and wall construction. This layout also utilizes all of the existing shipping/receiving docks which can support heavy distribution. The economic limitations to the rooftop greenhouse layout are from the size of the greenhouse and the production intensity it can support.

Figure 38 shows a second option for the attached greenhouse enclosure for the HDVGS:



Figure 38: Layout proposal for attached greenhouse on the ground floor showing the flow of materials for retail distribution

The 20 foot road boundary and delivery truck spatial requirements limit the amount of available land for the greenhouse to approximately 5,500 square feet which is the minimum greenhouse area discussed in the literature. The proposed layout supports all of the program spaces needed for production and distribution on the ground floor. The flow of materials from the greenhouse to the shipping and retail spaces is efficient in this version because the required spaces for production and distribution are in close proximity to one another.

This layout also causes the attached greenhouse footprint to overlap the proposed maneuvering apron for two of the three existing loading docks (see figure 33) making them less usable for large trucks and this may limit the site's wholesale potential. Parking is also limited by the greenhouse footprint in this layout which affects retail distribution potential.

This evaluation of two layouts shows that they have opposite economic issues to consider. The rooftop greenhouse has barriers to its production potential and the attached greenhouse model has spatial requirements that cause distribution issues. Both of the proposals should be further evaluated because they provide the adequate space for production and distribution and more investigation is needed in order to have enough information to choose one over the other.

3c. Technical issues and aesthetic impact –

Technical issues can be addressed by evaluating the age and condition of the building, the construction type, and the connection of the greenhouse and the building. These factors inform the startup costs and the amount of preparation needed for the BIA adaptation

proposal. This pragmatic evaluation may also expose unusual or unforeseen conditions that could affect the entire feasibility of the project or of using a particular turnkey system.

Structural floor plans and building sections can show many of the technical factors of the building and highlight any obvious issues for integrating BIA production. These technical drawings for the Las Vegas site are seen in figure 39.

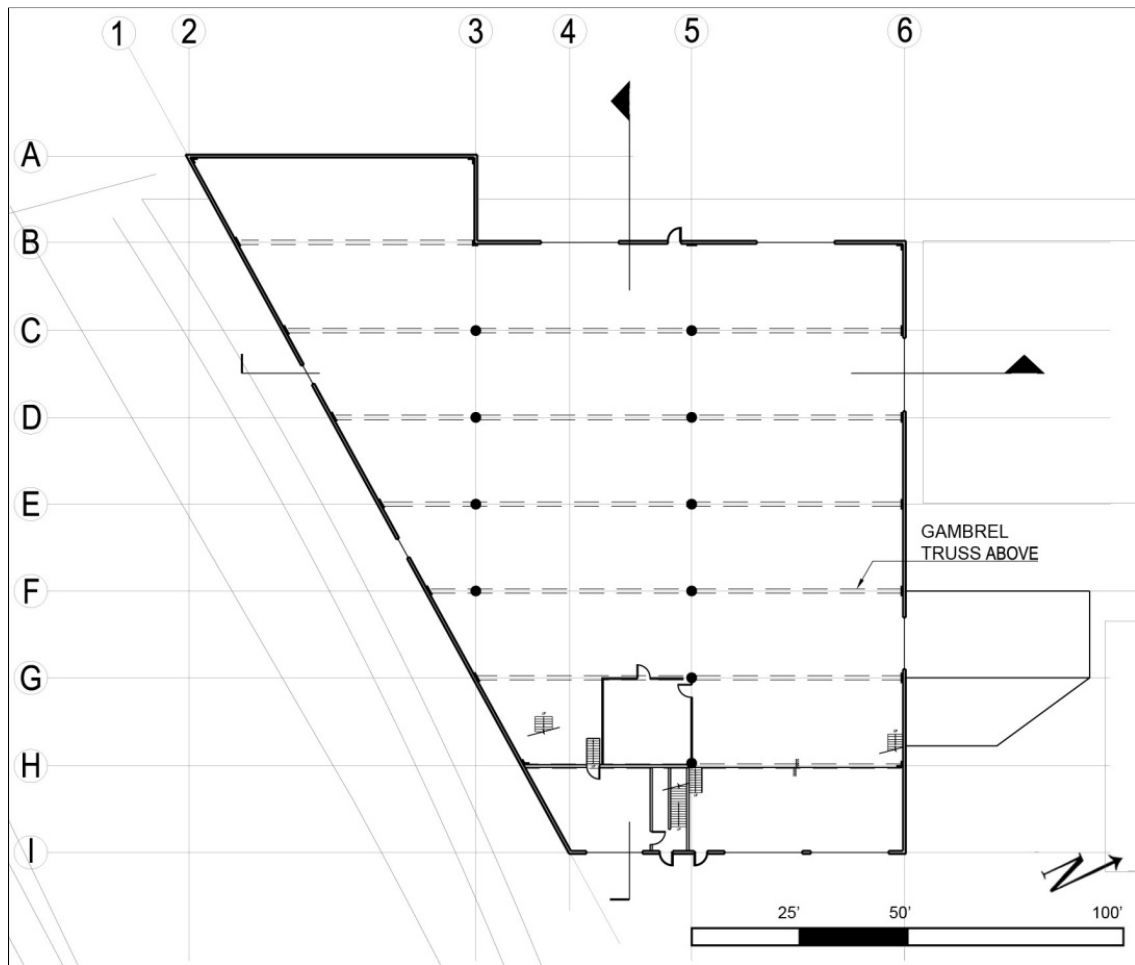


Figure 39: Structural floor plan with beams above and section call-outs.

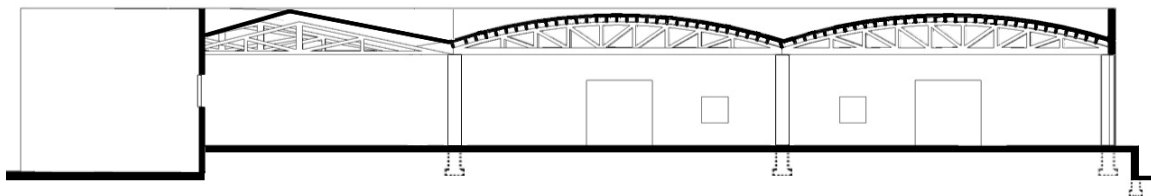


Figure 40: Building section looking west showing gambrel trusses. NTS.

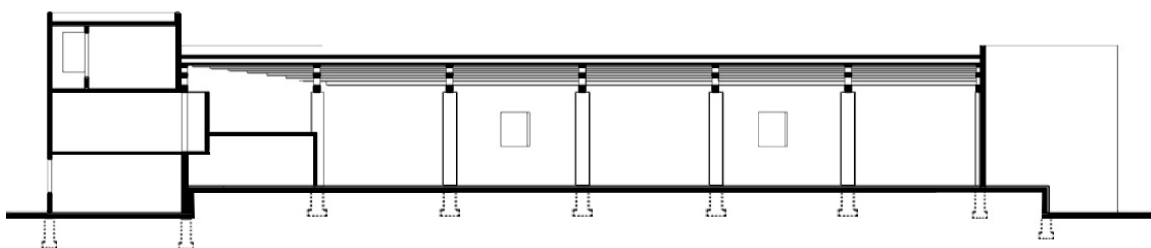


Figure 41: Building section looking south. NTS.

The structural plan and building sections of the Las Vegas building show that the front (east) façade of the building is an extension added to the structure at a later date. The main structure has walls of precast concrete panels and the extension is entirely CMU construction. Another important finding from the building section in figure 40 is that the gambrel-style trusses create a non-flat roof deck. This is an obvious structural engineering issue for the integration of a rooftop greenhouse because the greenhouse requires a level surface. The level of alteration needed to accommodate the rooftop greenhouse suggests that it should be removed from the list of potential turnkey systems.

Now that the list of potential systems is down to the attached greenhouse enclosure for the HDVGS, a demolition plan is a useful drawing to consider any technical issues with integrating the greenhouse into the site.

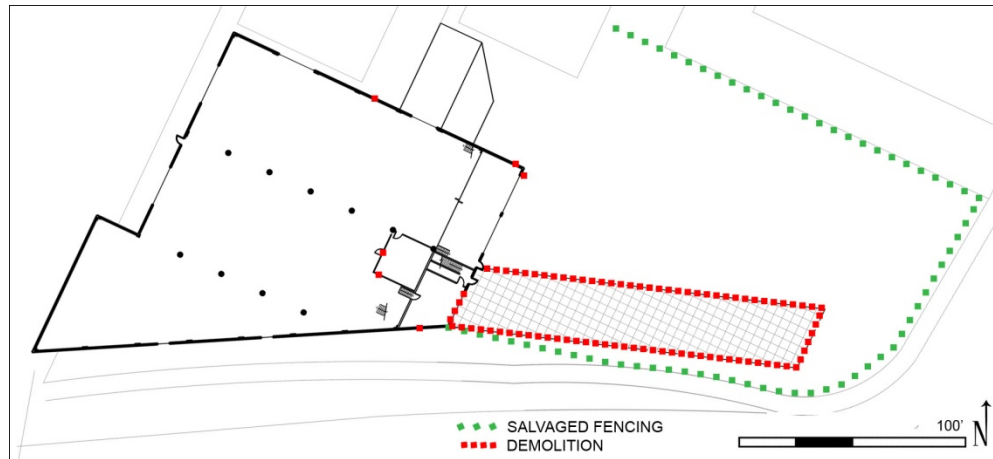


Figure 42: Demolition plan for VIG layout.

The demolition plan shows that few alterations are needed for the building but the parking lot will need to be removed and replaced with a drainable surface where the greenhouse is located. The demolition plan also documented the security fence which can be salvaged and adaptively reused as a structure for a greenwall or as façade structure to act as a wind breaker or to support shade cloths and for the greenhouse.

A detail showing the conditions at the greenhouse penetration can also reveal any technical issues that need to be considered such as waterproofing or structural considerations.

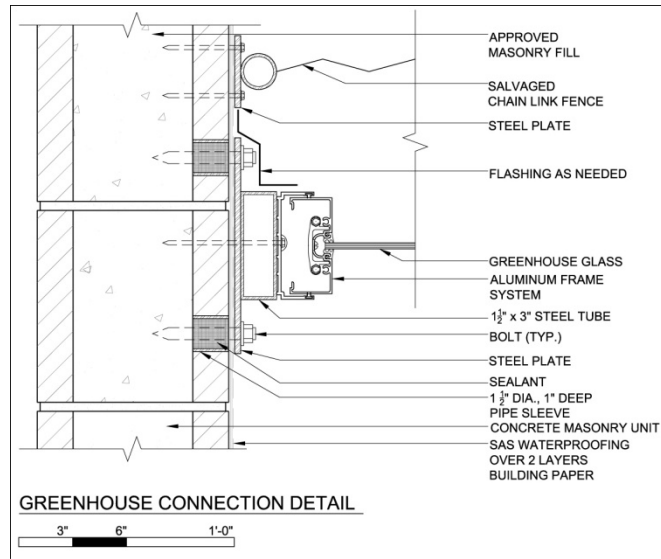


Figure 43: Connection detail of the greenhouse enclosure and salvaged security fence to the existing building.

Aesthetic impact is evaluated by the overall impact of the BIA adaptation on the site and the surrounding urban landscape. Since the architect ideally has been involved in the planning process from the earliest stages he or she will have a deep understanding of the project and a pool of information to draw from about the client and his or her needs. This information needs to be expressed in the design proposal for a successful urban farm. Renderings help in evaluating the aesthetics of the proposal.

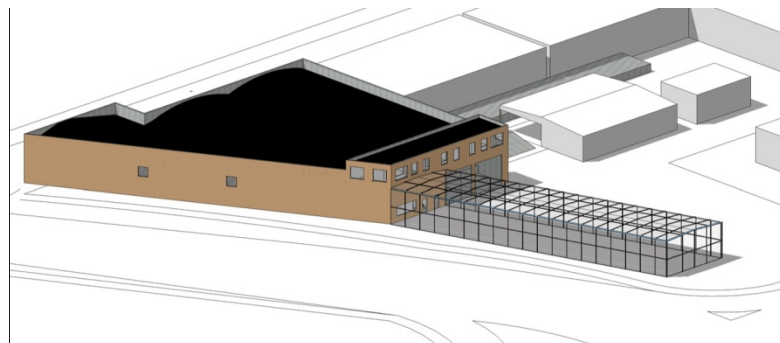


Figure 44: Rendering of enclosure for HDVGS attached to existing building. June 21st at 2:00 p.m.



Figure 45: Rendering of attached greenhouse using salvaged fencing as wind barrier and greenwall structure.
June 21st at 2:00 p.m.

This strategy outlined and applied in this chapter generates data at the end of each phase which help to verify the BIA proposal has been evaluated enough to move on to the next planning phase. This data reflects the most important factors that the architect will want to know once the BIA proposal has reached the design phase.

Using the strategy in the Las Vegas scenario described in this chapter helps in showing the type of detailed data that needs to be collected and verified by the client for the architect to begin the design phase of the planning process. The outline is structured for the architect and client, but it is also comprehensive and sufficiently flexible to be systematically adapted to fit the needs of other scenarios, planners, and locations.

For instance, in the scenario presented in this thesis a property was given to the architect and all of the information pertaining to the factors considered in the project scope and site selection phases was available except the type of BIA production system. The architect was able to take this data and use it to inform images that verified what the client had found. Once the architect verified that the project was ready for the site design phase, the factors that address the geographic and economic barriers are used to help in choosing a BIA system that maximizes the site's potential with the least impact on the adaptive reuse process. Based on analysis of these factors, it was determined that the existing building was most suited for an attached greenhouse HDVGS system. Once the turnkey system was

chosen, the architectural investigation into key technical issues and aesthetics was addressed using detailed drawing and schematic renderings of the proposal. In the case study analysis it was found that the HDGVS had a large aesthetic impact so this part of the investigation would most likely be developed in further discussions with the client; the facility designed for the Las Vegas site is only one of many possible schematic BIA solutions and but it is valuable to this research because it demonstrates how to work through the proposed planning strategy and arrive at an informed design solution for a BIA project.

CHAPTER 5

CONCLUSION

An objective of this thesis was to provide initial insight into how the architect/designer can help with successfully incorporating new high-performance agriculture technologies being developed for BIA into the urban landscape. In trying to achieve this objective, this research has proposed a planning strategy for urban farming in the form of BIA based on planning factors evaluated in the literature review and case studies.

It was found that defining the scope of the project is heavily influenced by local constraints and resources. Assessing these factors should result in an inventory of potential sites and a preliminary business strategy. Factors considered in the site selection phase help determine which of the available sites is best suited for the proposed project. A preliminary analysis of the site's potential should be performed using factors from the disciplines in the literature review. This preliminary analysis should result in the selection of a potential site which can be further analyzed in the site design phase. The site design phase should result in an informed decision on the feasibility of executing the project proposal using the chosen site. The constraints from the site and its surroundings inform a design that makes the highest and best use of the site. This critical phase of the design process requires the services of a professional architect/designer.

The Las Vegas case study demonstrates how the planning process can be applied to a specific site. The process was simplified to show how to consider the factors in each phase of the project. Each BIA system that was considered for the site was able to produce crops at a high intensity but the economic, structural, and spatial requirements to do so were found to be drastically different. The production system requirements and the site

constraints limited the list of potential systems to the attached greenhouse. Next, the greenhouse was shown in the locations it could functionally operate on the site by evaluating access and material flow patterns to consider the production and distribution potential factors of the site. Then, the technical evaluation of the existing building and its infrastructure showed that the greenhouse was best integrated as a lateral extension to the existing building. Finally, a design proposal for the BIA facility was created in response to the technical and aesthetic factors of the site and its surrounding constraints which could be used as part of a schematic presentation to a client.

The case study demonstrated how the planning strategy is used – especially the design phase, but the other phases of the planning strategy still need to be further evaluated so that they can produce the same level of understanding of factors to be considered in each phase as was shown in the site design phase for the Las Vegas case study. The first two phases are not typically in the scope of the architect's expertise so research from other disciplines is needed to help develop appropriate case studies for these phases of the strategy. Also, in reality, the aesthetic evaluation in the design phase of the Las Vegas case study requires much more development than was presented, including more design options and further investigation into how the design aesthetically integrates into the surrounding urban landscape. For the purposes of this thesis and without an actual client, however, it illustrates the type of information that can be produced by using the planning strategy.

A fundamental weakness of this research is that so little literature and so few built project examples specific to BIA exist that BIA was defined as a group of fundamental components for the research questions and literature review. It is debatable that planning for BIA is entirely based on planning for urban agriculture, planning for greenhouses, and

planning for building adaptation which were the key areas of the literature review. Thus, further investigation into how these areas of study act as the components of BIA would be helpful to make the argument more valid.

The social and economic benefits of local food production and adaptation of the existing building stock can be achieved by integrating BIA into the urban landscape. These issues are more important now than ever because currently the prices of low-quality and resource-intensive food is at all-time highs and natural resources are increasing valuable commodities. These issues also provide insight into the value of the developed BIA planning strategy in this thesis because the strategy offers a uniquely-compiled set of barriers to BIA, provided a resource for assessing the feasibility of a proposed BIA facility, and also helped define the role of the architect in BIA planning.

The relationship between BIA and architecture is a mutually beneficial because as BIA emerges as an industry its demand for architectural services will continue to grow. This dependence is due to the fact that planning for BIA pertains to the built form and it highlights the importance of the architect's unique ability to integrate the project at various scales and create experiences for the different users to help achieve a BIA facility that is successfully integrated into the urban landscape. This relationship also allows the architect to utilize his or her design skills for a worthwhile project type that has the potential to have a large positive impact on society and increase the architect's role in developing healthier communities.

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