Request for Proposals

Improving Food Security of Low Income Apartment Tenants

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Abstract

The purpose of this document is to request proposals for solution(s) which will increase the food security of Toronto's low income residents by means of urban agriculture, with a focus on increasing food production in or on rental apartment buildings.

Prof. Tarasuk defines food insecurity as, "the inability to acquire or consume an adequate diet quality or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so" [1]. The prevalence of food insecurity in Toronto is the highest in Ontario, at 10.1% [2]. The goal of this proposal is to solicit a solution focused on improving urban agriculture in/on low-income apartment buildings. Urban agriculture is chosen as the problem scope due to a combination of environmental, social and economic sustainability considerations: land shortage, urbanization, energy cost and social needs of the community in question.

The major stakeholders involved are low income tenants, landlords, urban agriculture organisations, and the City of Toronto. Specific communities which currently operate traditional gardens, indirectly expressed their desire to increase food production [3], and collaboration with specific pilot communities is possible and welcomed. A major point in favour of urban agriculture as a solution space is that almost all major stakeholders have demonstrated significant interest in solving this problem. They are expected to embrace a feasible solution if such is found and properly introduced. Landlords, however, often object to urban agriculture efforts on building, as such their needs/wants must be taken into considerations.

As an engineering problem, urban agriculture introduces many challenges. These include structural concerns, health and safety, accessibility, growing conditions, and sustainability. However, it provides an open solution space, as demonstrated by the selected reference designs. Current solutions are considered insufficient, and as such, the solution must be either a substantial improvement to an existing method or a novel solution. The design team is encouraged to test their solutions in a pilot area. If a pilot area is not selected, the design should be as generally applicable as possible to low-income apartment buildings (as justified by the respondents). The solution must be demonstrable for evaluation by apartment landlords and not-for-profit organisations in a showcase setting.

Keywords: food security, urban agriculture, food banks, community gardening, low income, Toronto

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1 Introduction

Prof. Tarasuk defines food insecurity as, "the inability to acquire or consume an adequate diet quality or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so" [1]. According to the Canadian Community Health Survey (2004), the prevalence of food insecurity in Toronto is the highest in Ontario, at 10.1% [4]. It is clear from contemporary research [5] and from discussion with stakeholders [6], that this is still a relevant issue that has yet to be resolved. Research conducted by Prof. Tarasuk[1] at the University of Toronto also showed that low income and living in rental dwellings were strongly correlated to food insecurity in Torontonian households [4]. As such, the focus of this document is on food insecurity as it pertains to the community of low-income apartment tenants.

Food insecurity leads to disrupted eating patterns since households struggle to obtain enough food to survive [5]. This limited access to nutritious food has been linked with nutritional deficits [7] and iron deficiency anaemia in children [8]. As such, food insecurity can have a significant impact on an individual's quality of life.

The purpose of this document is to request design solutions that improve the food security of low-income Toronto residents with such need by facilitating the production of food in or on apartment dwellings. This goal is consistent with the Toronto Food Strategy and Tower Renewal Project by the City of Toronto (see Appendix B). This document will first discuss the feasibility of urban food production, followed by a detailed stakeholder analysis. This will be followed by an outline of the project requirements.

2 Prior Attempts

Several main methods have been identified for mitigating food insecurity: charitable food assistant programs [9], addressing food access problems [10], community-based initiatives [11], expanding food animation [10], and increasing/innovating food production [10]. In Toronto, these are manifested in the form of community kitchens, food banks, and urban agriculture. Urban agriculture is a promising area for further development as a major tool to increase food security of Toronto's low-income tenants. It has the potential to be an effective solution since it is environmentally, economically, and socially sustainable. This section outlines some of the key issues regarding the above considerations, and offers a rationale for the choice of urban agriculture as a solution space.

2.1 Land shortages

Prof. Despommier of Columbia University warns that not enough land will be available to feed the growing world's population using only traditional agriculture methods in the near future [12]. In Toronto, the

[1] Using data, from the Ontario Share File of the 2004 Canadian Community Health Survey Cycle 2.2, the analysis was performed using multivariable logistic regression.

population increases by 4.5% between 2006 and 2011 to 33,467,688 [13]. As such, food production methods that are less reliant on land availability, such as certain types of urban agriculture, may become a necessity for society in general.

2.2 Urbanization

It is estimated that 60% of the world's population resides in urban settings today, a number that will increase to 80% by the year 2050 [12]. However, this population cannot work and contribute directly to traditional agriculture due to the typically distant location of rural farms. At the same time, of new food bank clients, 35% require the services of a food bank because they lost a job, and 22% due to a disability [14]. Research done by Hamer in the UK, found that disabled people are likely to spend more time at home than non-disabled people [15]. A study done in the US also found that unemployed people are likely to spend more time idly than employed people at home [16]. By engaging these people (and others) in domestic urban agriculture through accessible growing methods, we can utilize human resources that would otherwise not be able to contribute to food production. This both ameliorates the food security of those in need and alleviates some of the pressure on the traditional food supply.

2.3 Energy Cost of Food

Research done in the Waterloo region found that food bought in the region travelled an average of 4,497 km to stores before being bought [17]. This transportation consumes a significant amount of fuel. The total energy use in the North America food system is equivalent to nine barrels of oil per person per year [17]. As such, the rising price of oil leads to significant rises in the price of food [17]. Given that an increasing fraction of the population is living in urban settings [12], food produced within city limits would have to travel far less, and thus be more economically and environmentally sustainable.

2.4 Societal/Economic factors

Food banks rely heavily on third party charitable donations [18]. Furthermore, many individuals experiencing food insecurity prefer to stay hungry than receive charity [19]. Creating this class dependency and social divide is not socially sustainable. Soup kitchens and food banks cannot meet the complete hunger needs of their clients as they are set up as emergency programs [20]. This reliance on charity is also economically unsustainable, as it is an immediate response, but not a self-reliant means of routine food acquisition [22]. Clients of food banks have also expressed dissatisfaction with the food served, in terms of amount, variety and nutritious value [23]. As a result, researchers have made claims against food banks as being ineffective in both the short term (preventing hunger) and the long term (addressing the structural causes of food insecurity) [23].

On the other hand, urban farming enables the user to become food secure without long-term reliance on charity, which empowers the individuals [6]. As such, urban agriculture is a more socially sustainable than reliance on food banks. Urban agriculture also has positive spin-offs. It contributes to social sustainability, by engaging the community to work on the same project for common benefits; encourages social inclusion, by providing fresh food to the poor; creates green spaces for recreation; and provides the opportunity for education and employment [24], by allowing users to work in gardening and hence indirectly providing them with related skills.

2.5 Summary

From the perspectives of sustainability and effectiveness, urban agriculture is a promising solution for reducing food insecurity. As such, we limited the solution space of the proposal to urban agriculture, in the form of gardening (that is intended for food production) in/on low-income apartments at both the individual and community level.

3 Engineering Problems

Individuals and communities can grow food using the land around their homes, on rooftops, or on balconies [24]. Several methods used include container farming, vertical farming, green house, hydroponics, and extensive or intensive green roof systems [3] (refer Appendix A for definitions). This section will outline some of the current engineering issues that urban agriculture is facing. The problems are structural loading limitations, water supply and drainage systems, weather and environmental conditions, space management, accessibility, and safety.

3.1 Loading

Apartment buildings are not designed for agricultural purposes. Therefore, structures often cannot withstand the loads required for substantial amounts of gardening. This is especially an issue for rooftop farming, as existing building roofs are designed for a live load of 1.5kPa, which is only sufficient to grow lettuce on 7.5 cm of compost [25]. Additionally, most apartment buildings in Toronto were built in 1960-1969 [26], and as a result often experience age-related structural issues such as balconies falling apart and water leakage [26]. Although structural renovation can increase load-bearing capacity [24], it is expensive and not necessarily economically feasible for low-income apartment buildings. As such, the greatest barrier of rooftop gardening is the cost of building green roof structures and reinforcing the building to support the extra load [27].

Even with stronger roof structures, these loading limitations cap the maximum depth of the soil allowed to as little as 20 cm [29]. With this depth of soil, the variety of plants that can be grown is still quite limited [29] (see Appendix C for more information). During the winter, snow accumulation will increase the loading on roofs [30]. As a result, planters often have to be moved indoors during winter to ensure the safety of the structure [25], which can be a transportation issue due to the heavy weight of the planters [31].

Figure 1: The growing beds collapse under the weight of soil

Soil has high density and is heavy, and may cause the bottom of the bed to fail [33], suggesting that load is an important consideration in urban agriculture in the structural safety context. [Picture taken at South Riverdale Community Health Center Rooftop Garden]

Aside from the rooftop, the Ontario Building Code specifies that minimum specified loads for exterior balcony, apartment storage area, and sleeping and living quarters as 4.8kPa, 4.8kPa and 1.9kPa respectively. This will allow greater depth of soil compared to rooftop gardening, but limited space on balcony and unfavourable indoor growing conditions can be an issue (refer to Section 3.3 and 3.4).

3.2 Water Supply and Drainage System

Since insufficient water causes stunted growth and excess water suffocates the plant [32], issues relating to the continuous supply of water and drainage are raised. For rooftop gardening, the roof must be able to hold and drain rainwater effectively [24].

As discussed in Section 3.1, the maximum allowable load on rooftops results in difficulties collecting rainwater on the roof. The same considerations also lead to low depth of soil, thus necessitating frequent watering as the soil dries out more quickly [25]. Some rooftop gardens have rain barrels, but rarely use them [33], or find that the supply of water is inconsistent [29]. In addition, water is often used up quickly during the summer due to higher evaporation rates. A possible solution for these issues is to use the municipal water supply [29]. Similarly, balcony gardeners often use hoses and self-watering containers to supply water to plants [34]. Compared to municipal water sources, reuse of stormwater and wastewater for agriculture could be more environmentally sustainable [35].

The second element to consider is drainage. Although research has shown that urban agriculture can help reduce and delay runoffs [36], drainage can be problematic for balcony, rooftop and container gardening. The ability of plant roots and soil to retain water can put the building in contact with moisture for an extended period [29]. Frequent wetting of the balcony often results in corrosion of reinforcing steel and fracturing of concrete at the slot [37]. Due to the high weight of water (0.22 kg/m^2 per inch of depth), an improper drainage system may cause the floor structure to collect and form standing pools [30]. This in turn causes the structure to deflect and attract more water, resulting in ponding failure [30]. In addition, if rain barrels are used to collect water on rooftops, heavy rain must be taken into consideration as it can fill the barrels quickly and flood the garden [29].

It is also important to note that excess water in any water storage container will freeze during winter, causing the container to crack [33]. However, if a spout is available to drain the excess water without having a proper drainage system, it may cause dispute between neighbours due to water runoff [34], which is often dirty [33]. Furthermore, these sediments can clog existing drainage system [37].

3.3 Weather and Environmental Conditions

Technical issues also arise due to the climate and weather conditions of the city of Toronto. The issues discussed are high-speed winds, hot and dry summers, and sub-zero winter temperatures.

Rooftop gardens and balconies are subjected to strong lateral winds. This is due to the facts that wind speed doubles every 10 storeys of the building [39] and more than half of the rental apartment buildings in city of Toronto are over five stories high [40]. High winds blow away soil and vegetation [24], and dry out the soil quickly [29]. However, wind loading is not necessarily a concern unless the container is light enough to be displaced by wind [33].

Toronto's climate poses significant issues to urban agriculture during the summer when daylight is long and temperature is high. During the summer, excessive sunlight can cause deterioration of materials and components present outdoors [24]. In addition, water in self-watering containers may heat up, causing possible health concerns as the plastic may leech into the water when heated [33]. Temperature also has an impact on plant growth. Outdoor plants have to be protected from high heat caused by light reflection from pavement [41]. In general, the optimal temperature range for plant growth is 21-27°C during day and 18-21°C during night [32]. Temperature drop allows plants to conserve food produced during the day by reducing respiration rates [42]. For indoor gardening, adequate lighting is an important factor. It is affected by the presence of shade, wall colour, window curtains, day length, time of day, and time of year [32]. Balconies can thus have too much or too little sunlight, depending on the direction the balcony faces [34].

During the winter, food production slows significantly unless a greenhouse system is installed. Water reservoirs must be emptied and covered to prevent accumulation of snow [43]. If not, they will exert an increased load on the floor structure [43]. The harsh weather conditions limit the growing season by delaying the planting seasons and ending the harvesting season earlier, leading to reduced food production. A general rule of thumb is that May 24 is the earliest day when farmers can start growing seedlings without having them die due to freezing [33]. During autumn, the farmers have to clean up and prepare their gardens before the first frost, which is October 6 [44]. Although seedlings can be grown indoors before the planting season begins, getting sunlight indoors and moving the seedlings to actual growing beds are challenges that have to be considered, requiring greater amount of care and maintenance [33]. This can be a barrier for farmers with less expertise [31].

Figure 2: Cold frame for extending winter

Putting a tent-like structure called tarp over the garden will help to make it a green house, which can help to extend growing period. However, the use of tarp might be unsafe as the high wind poses risks to the structure [25]. Figure courtesy of [38].

3.4 Space Management and Accessibility

Among new food bank users (6 months or less), 22% have reported a disability [14]. Interviews with local community garden coordinators also revealed that many of the gardeners are mobility impaired [6,33], resulting in the need for a barrier-free design. In response to this need, many containers and growing beds currently used by community gardens are raised above floor level [33].

In order to reduce the shear force exerted on the floor structure, most containers and heavy growing media are placed near structural members to transmit load vertically into the structure [43]. However, this adversely affects space management [33]. The ability to spatially arrange the beds become limited, and the design may no longer properly address the needs of the mobility impaired (See Appendix D for accessibility design guidelines). Access to rooftop gardens is often difficult, involving ladders and climbing [45]. This poses another significant barrier to the mobility impaired.

3.5 Safety

Since the growing beds are raised for a barrier-free design (as discussed in Section 3.4), these containers can pose a physical safety risk. Children can climb on top of them and accidentally fall off the rooftop or balcony [33]. Ontario Building Code 3.3.1.17 states that guards no less than 1070 mm high shall be provided [28]. However, the height difference between containers and guard are often less than this specified value [33].

Figure 3: Safety risk of containers

The containers allow children to step on it and climb over the guard, causing the effective height of the guard approximately half of its original height. [Picture taken at South Riverdale Community Health Center Rooftop Garden]

Humidity can pose another safety concern. Most indoor plants that are from tropics prefer high humidity, as it helps to prevent rapid transpiration and reduce water loss [32]. However, in humid conditions, moisture becomes a major concern when growing plants indoors, as walls and structural components may become infested with mould [33]. Also, household plants (5 to 7 average size) produce 0.86-0.96 pints of water vapour a day [46], which also contributes to mould growth. This can lead to health concerns [32]. Improved air circulation, drainage to the exterior, and insulation are methods of mitigating this problem [46].

In term of fire safety, green roofs can help to slow down the spreading of fire to and from the building via the roof (especially when the growing medium is saturated) [48]. However, when dry, the plants themselves can present a fire hazard [48]. For concrete and structural steel, the yield plateau occurs at a lower stress as temperature increases [49]. This suggests that the structure will undergo deformation and failure at a lower load if it catches fire [49].

3.6 Summary

The following list is a brief summary of all of the basic considerations that need to be met:

- Rooftop and/or balcony loading limit
- Current {state, condition} of the building
- Collection and drainage of water
- Wind
- Seasonal climate fluctuations
- Space management and accessibility
- Physical safety of users
- Pests and mould

4 Reference Designs

In Section 3, the engineering issues related to the current practice of urban agriculture are discussed. A significant improvement over these current practices is desired. As such, this section will describe some sample designs related to the problem that were deemed to be innovative, with the intention of encouraging more creative respondent designs. The form and function of each reference design will be summarized, followed by a discussion of their flaws. The designs presented are the Hydroponic Drip Garden, the Garduino, the Grow-at-home mushroom kit, and the Backyard aquaponics system.

4.1 Hydroponic Drip Garden [50]

Figure 4: Hydroponic Drip Garden

This DIY hydroponic system works by supplying water and nutrient solution from the 'reservoir' (yellow box below) to the growing medium, with the help of water pump. Nutrients will drain out from the growing medium back to the 'reservoir' to be circulated again. The process repeats with the help of a timer. Lighting is provided artificially with a 400W HPS (High Pressure Sodium) grow-light. The set up cost of this 27-gallon hydroponics system is around 70 USD.

This system is difficult to maintain, as dirt enters the reservoir over time. The system cannot be moved easily due to the amount of parts and complex connections between devices. Also, the water tends to leak out from many interconnecting pipes. The moist conditions also promote the growth of mould. Only a limited variety of plants are suitable for hydroponics [51], and it is usually most successful with lettuce, tomatoes, cucumbers and peppers [52].

4.2 Garduino = Gardening + Arduino [53]

Figure 5: Garduino = Gardening + Arduino

This design regulates the growing conditions of the plants, using multiple sensors and a microcontroller. The user has to concern themselves less with the details of growing the plants, as the Garduino automatically waters the plants and adjusts lighting conditions. The approximate cost of this project is about 100 USD, but can be highly variable given the DIY nature of the project.

There are concerns about the safety of the system, as users reported some electrocution felt when operating the system. This can become more serious if spills were to occur on electronic components. Also, the system is difficult to maintain and relocate, due to the abundance of separate components.

4.3 Grow-at-home Mushroom Kit [54]

This mushroom kit allows users to grow their own mushrooms, simply by opening the box, providing moisture to the contents, and harvesting after about 10 days. The kit is reusable, providing at least two harvests, with a production up to 1.5lbs of mushrooms. Also, the soil in the kit is environmentally sustainable, as it is made entirely of waste coffee grounds from Peet's Coffee and Tea. In addition, all components of the kit are either recyclable

Figure 6: Grow-at-home Mushroom Kit

or compostable.

Despite these benefits, the mushroom kit is expensive, costing about 20 USD per kit (not including shipping.). This amounts to an expected 29.4 USD per kg, which is far more expensive than the retail price of canned oyster mushrooms ($4.67 per kg of canned oyster mushroom at Walmart, as of March 2012 [II]). Also, the acidic nature of coffee grounds [55] limits the variety of food that can be grown in it.

4.4 Aquaponics [56]

Aquaponic systems produce both fish and vegetables, using the waste produced by the fish to provide nutrients for the plants. As such, the system requires no input of plant nutrients, unlike conventional hydroponic units. The system shown consists of 5 plant beds with 1 large fish tank, produced by Backyard Aquaponics Pty Ltd., of Australia. A system with 3 beds and 1 fish tank can produce up to 75kg of fish yearly. Note also that the raised beds provide accessibility for senior citizens and mobility-impaired individuals.

Figure 7: Aquaponics

However, the 3 bed system has an initial cost of $5265.00 AUD ($5580 CAD), a very high initial cost. The system, if placed outside, would not be operational for much of the year in Toronto due to winter. This system is limited in terms of what can be grown, in the same way as the hydroponics system shown in Section 4.1.

5 Stakeholders

In addressing the problem of food insecurity in Toronto, there are many stakeholders involved in this project. The primary stakeholders are low-income apartment tenants, the landlord or the owner of the apartment, community garden organizations, and the City of Toronto. The analysis of minor stakeholders is discussed in Appendix E.

5.1 Low-Income Apartment Tenants

The low-income nature of the community means that they have little income to spend on food (as little as $22 monthly after rent [6]). As a result, they would only be interested in solutions that cost them very little financially. Utcha Sawyers of Foodshare indicated that many people in this community are elderly and/or mobility impaired [6]. Thus, they would want the solution to be accessible. Communities that operate traditional community gardens successfully, but recognize these gardens are limited by nature, would probably also be receptive to other methods of food production.

[II] This pricing information is found on http://www.walmart.com/ip/Roland-401848/17770872, as of March 4, 2012, by dividing the price by the net weight of oyster mushroom. The reason we chose to compare with canned food is because most low-income individuals tend to prefer canned fruits and vegetables, as shown in [57].

Food deserts are areas more than 1km away from a grocery store [57] (Refer to Appendix F). If the particular apartment falls in the area of food desert, residents will have difficulty accessing food retailers. Residents of food deserts have an especially hard time during the winter when travelling is difficult. These residents would desire food during the winter such that during a snowy and hard week they will not need to leave the house but will have a sufficient supply of food at their building [33].

5.2 Owner of Apartment/Landlord

One of the major challenges in apartment farming is the reluctance of the landlord or the apartment owner to allow users to utilise public spaces in the apartment for farming purposes, especially the rooftop [24]. Landlords are concerned about possible damages to the building, including moisture damage, flooding due to improper sealant, and unsafe loading conditions [6].On the other hand, some landlords see apartment gardening as an asset and support it for aesthetic and marketing purposes [34]. The owners are also typically responsible for building maintenance, so any solution should result in a minimal increase in building maintenance. In addition, any design should minimize the risk of property damage due to the above issues. If these conditions are met, the landlord would be far more likely to agree to allow tenants to use their property for urban agriculture.

5.3 Existing Urban Agriculture Organisations

There are many organisations involved with urban agriculture in Toronto. The Toronto Community Garden Network, for example, encourages a healthy community gardening movement in the City of Toronto to make gardening an integral part of city life [58]. These volunteer-based projects have existed for several years, and are often staffed by low-income community members [6,33]. Many are trying to improve the scale of production by having bigger beds [33], and by extending the planting and harvesting seasons [6]. Such organisations are not only a good source of reference designs, but often act as community representatives and manage community projects. This poses them as important interface between the affected community and institutional stakeholders.

Some organisations are also looking for a more self-sustaining system without much need for maintenance and expertise in farming [6,31]. This would make urban agriculture more accessible to the general public and will encourage more people to start farming at home.

5.4 The City of Toronto

The City of Toronto has expressed significant interest in tackling food insecurity, recognizing the potential of urban agriculture. Toronto's Food Charter states that the city council will encourage community gardens that increase food self-reliance and support urban agriculture to promote food security [59]. To this end, the City of Toronto is working on the Toronto Food Strategy with one of its priority areas being the expansion of urban agriculture into residential buildings [10].

Although not explicitly mentioned in the implementation handbook of the Tower Renewal Project, growing food in or on apartment buildings will also satisfy the three main objectives of the initiative (see Appendix B) [60]. This tower renewal project includes a partnership between 23 city divisions, public and private stakeholders [60]. However, among them, Toronto Environment Office and Toronto Community

Housing Services are relevant within the foci of urban agriculture in/on low-income apartments. However, these divisions, when contacted, did not respond to the request for more information.

The city has also expressed interest in urban gardening, in the form of green roofs. The City of Toronto's Green Roof Bylaw states that a green roof is required for new commercial, institutional and residential development with a minimum Gross Floor Area of 2,000 m^2 as of January 31, 2010 [61]. The City also offers an incentive of $50 per square metre up to a maximum of $100,000 for eligible green roofs [62], which is also applicable for existing buildings [63].

6 Project Requirements

This section outlines the high-level objectives, project-level constraints, and the detailed objectives to evaluate potential candidate designs. Designs that are innovative, or offer a substantial improvement upon existing methods will be preferred.

6.1 High Level Objectives

1. Design a {economically, environmentally, socially} sustainable solution for growing food {in, on} low-income apartment buildings
2. Enable the users to increase the amount of {fresh food, nutritious content} in their diet
3. Design a solution that holds paramount the safety of the {user, community, property}

6.2 Project-level Constraints

These constraints do not relate to specific criteria and metrics. Instead, they relate to the deliverables, the pilot area, and the respondents' design process.

- The design MUST adhere to all relevant building codes, as dictated by the nature of the solution (see Appendix G).
- The solution SHOULD be designed for ease of transportation and relocation
- The design team SHOULD choose a pilot area in which to test their designs[III]
- Any selected pilot area MUST have at least 50% of their population be low-income (see Appendix H)
- The design MUST include a maintenance plan
- The design MUST be demonstrable for evaluation by apartment landlords and not-for-profit organisations in a showcase setting.

6.3 Detailed Objectives and Criteria

In the following table, detailed objectives are developed based on the higher-level objectives. These are further broken down into specific wants, which are given appropriate metrics, gradients, and related constraints (if any). Several metrics do not have associated constraints, due to limited information available in

[III] In the event that a pilot area is not chosen, the design team may come out with a non-location specific solution that is applicable in general to low-income apartment buildings.

a reasonable amount of time. Furthermore, several metrics are dependent upon the scale of the respondent design; placing constraints upon these would unnecessarily limit the solution space. As such, these constraints will be left to the engineering judgement of the respondents, and might emerge through interactions with stakeholders during the design phase.

	Criteria		**Constraints**
	Metrics	**Gradient**	
1. Produces fresh food for apartment residents by increasing access to and production of local food			
Gross annual food production	Mass of food produced annually	More is better	N/A
Space efficiency of the solution	Mass of food produced annually per square metre of covered floor space	More is better	N/A
Variety of food that can produced	Maximum depth plant's roots can grow to (refer Appendix C)	More is better	> 20 cm
Growing season	Fraction of the year that fresh produce can be obtained from the solution	More is better	> 40% of the year [IV]
2. Is safe for the {user, community, property}			
Mould resistance of materials used	Performance as per the ASTM D3272-00 test method [65] and ASTM D3274-09 evaluation method [66] (Rating scale)	Higher is better	Ideally 10
Child safety	Risk of a child being harmed directly/indirectly due to the solution [64]	Less is better	Ideally 0
Flammability of materials	Flame spread rating as per the CAN/ULC S102.2-10 [67]	Less is better	< 75 [V]
Flammability of plastic components	Performance of plastics material under UL94 testing procedures [68]	More is better	Must be V0
Loading on structure	Ratio of total allowable load to the maximum loading induced by the solution	More is better	> 2.0 [VI]
Moisture damage to the structure	Risk of moisture damage annually	Less is better	Ideally 0

[IV] The growing season in Toronto is 149 days, which represents 40.8% of the year.
[V] Requirement of the National Fire Code 2010 Division B Section 2.3., and National Building Code 2010 Division B Section 3.1.13.
[VI] Design has to account for a load factor of 1.5, as defined in National Building Code of Canada 2010 Division B Section 4.1.3.

3. Is environmentally sustainable in the context of {food production, design materials}			
Dependence on municipal water supply	Litres of municipal water used per month	Less is better	N/A
External energy consumption	Kilowatt-hours consumed per month	Less is better	N/A
Recyclability of materials	Percentage of materials used that are collected for recycling by the City of Toronto [69]	More is better	N/A
4. Is socially sustainable in the context of easy {use, maintenance}			
Easy to clean	Total time (in hours) spent cleaning annually	Less is better	N/A
Longevity of the solution	Total operating lifetime (in years)	More is better	> 1 year [VII]
Knowledge barrier for use	Average time (in hours) required to train users to produce food	Less is better	N/A
Time efficiency (time spent working plots vs. amount of food produced)	Mass of food produced per hour of time invested (in kg/h)	More is better	N/A
5. Is economically sustainable in the context of low-income {households, communities}			
Start-up cost	Cost to begin operations, in CAD$	Less is better	< $100 / person [VIII]
Long-term cost	Annual operation costs (incl. maintenance) in CAD$ per user per year	Less is better	< $120 [IX]
Cost efficiency (cost spent vs. amount of food produced)	Cost of one kilogram of food	Less is better	< $2/kg [X]
6. Is accessible to senior citizens and mobility impaired individuals			
Accessibility of the solution	The extent to which it complies with the City of Toronto Accessibility Design Guidelines, where applicable	More is better	Should be fully compliant

Table 1 – Table of Detailed Objectives, Criteria, Metrics and Constraints.

[VII] This corresponds to at least one growing season and one winter.
[VIII] Most designs for household food production in Section 4 of "Reference Design" are below $100, with a few exceptions.
[IX] As stated in Section 4.1, low-income households can have as little as $22 after-rent income per month. $120 is ~50% of the annual income of these households.
[X] Cost of fresh white, red & Yukon potatoes at Longos is $2.18/kg, as of March 2012.

Appendices

Appendix A – Definitions

Apartment Gardening/ Apartment Farming: A variation of urban agriculture on apartment buildings. See *urban agriculture.*

Bearing capacity: Bearing capacity is the ability of soil to safely carry the pressure placed on the soil from any engineered structure without undergoing a shear failure with accompanying large settlements [70]

Container farming: A micro model of farming where a family unit or household is producing fruits and vegetables in special containers for personal consumption [71]

Extensive Green Roof System: A green roof system that has a shallow growing medium that is designed to support self-sustaining vegetation, requiring less maintenance than intensive systems [72]

Food Desert: An area in which the nearest grocery store is over 1 km away [57]

Food Insecurity: The inability to acquire or consume an adequate diet quality or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so [1]

Food Security: A condition in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life [73]

Green Roof: An extension of an above grade roof, built on top of a human-made structure, that allows vegetation to grow in a growing medium and which is designed, constructed and maintained in accordance with the Toronto Green Roof Construction Standard [72]

Hydroponics: The growth of plants using a water solution instead of soil [74]

Intensive Green Roof System: A green roof system that has a deep growing medium that supports a variety of landscape design and growth [72]

Market housing: Market rent unit, a unit without rent or income subsidies, whose rent value is determined by what the same unit would command in an open market [75]

Quality of Life: The degree to which a person enjoys the important possibilities of his or her life [76]

Sustainability: Sustainable development, which is to meet present needs without compromising the ability of future generations to meet their needs [77]

Urban agriculture: the growing of plants and the raising of animals within and around cities, integrated into the urban economic and ecological system [78]

Vertical farming: A living cladding system for plants to grow up or against building's facade [79]

Appendix B – Current Initiatives by the City of Toronto

B1: Toronto Food Strategy

The development of a food strategy for Toronto was proposed during a board meeting on June 2, 2008 [80]. The Food Strategy is an active project, with Toronto Food Policy Council as the key player [81]. The most recent report was released in May 2011, known as "Cultivating Food Connections: Towards a Healthy and Sustainable Food System in Toronto", which proposes six directions for food system renewal [82]:

- Grow food-friendly neighbourhoods;
- Make food a centerpiece of the new green economy;
- Eliminate hunger;
- Empower residents with food skills and information;
- Connect city and countryside through food; and,
- Embed food system thinking in City government.

The report also mentioned the unhealthy diet of children and youth, and the poor quality of food available through food banks as few of the key themes emerged during the consultation and engagement process [10]. Many are also interested in growing food for consumption [10].

B2: Tower Renewal Project

This project is an apartment community improvement initiative, proposed in September 2008 [60]. This project aims to transform old apartment buildings to achieve:

- A cleaner and greener city
- Increased social and cultural benefits and stronger communities
- Improved local economic activities

Although urban agriculture is only a subsection of the project [83], it can contribute significant benefits to the main objectives of the tower renewable project, as discussed in Section 2.0.

Appendix C – Soil Depth Required for Different Plants

The following information is obtained from Reading International Solidarity Center (RISC)'s edible roof garden. The information provided should serve as a guideline, rather than a mandatory code or standard.

	minimum depth of container in cm
veg	
aparagus	45
aubergine	20
beetroot	25
beans: French & runner	20
beans: dwarf & bush	15
broad beans	20
broccoli, calabrese & cauliflower	25
cabbage & kale	20
carrots	20
celery & celeriac	not recommended
courgettes & summer squashes	25
cucumber	20
endive & chicory	20
Florence fennel	20
garlic	15
kohlrabi	15
leeks	20
lettuce	10
okra	25
onions & shallots	15
oriental greens	10-15
dwarf parsnips	20
sweet peppers & chillies	20
peas	15
potatoes	30 (best in towers)
sweetcorn: traditional	30
sweetcorn: dwarf	20
tomatoes	20
turnips	20
perennial salads	
chickweed	10
chives	10
corn salad	10
dandelion	10
daylily	20
garlic mustard	15
good King Henry	15
nasturtium	15
salad burnet	10
sorrel	15
rocket	10
land cress	10
Eygptian tree onion	15
rhubarb	30
Welsh onion	10
winter purslane	10
fruit	
apple	40-60
cherry	45
dwarf citrus	20
mulberry	not recommended
figs	45
peach, apricot, nectarine	45
pear	unreliable
plum	45
quince	60
kiwi	30
grapes	45
melon	20
blackcurrant	30
red & white currant	30
gooseberry	30
blueberry	45
autumn raspberry	30
strawberry	20
blackberry, loganberry & tayberry	unreliable
herbs	
basil	7
borage	20
coriander	7
chervil	10
dill	25
fennel	25
lavender	20
lemon grass	25
lemon balm	20
lovage	25
marjoram	10
mint	15
parsley	20
rosemary	20
sage	20
savory	15
sweet bay	30
sweet cicely	20
French tarragon	25
thyme	15

[84]

Figure 8 – Suggested minimum depth of container to grow different vegetables and fruits

The information below with more details on the growing conditions of vegetables in containers is provided by Diane Relf, Retired Extension Specialist, Horticulture, Virginia Tech [41].

Information for Growing Vegetables in Containers				
Vegetable* Light Requirement**	Minimum Container Size	Distance (inches) Between Plants in Containers	Days from Seed to Harvest	Comments
Beans, bush FS	2 gal.	2-3	45-60	Several plantings, two-week intervals
Beets FS/PS	1/2 gal.	2-3	50-60	Thin plants when 6 to 8 inches tall
Carrots S/PS	1 qt.	2-3	65-80	Several plantings, two-week intervals
Cabbage FS/PS	5 gal.	12-18	65-120	Requires fertile soil
Chard, Swiss FS/PS	1/2 gal.	4-6	30-40	Harvest leaves for long yield
Cucumbers FS	5 gal.	14-18	70-80	Support vining types
Eggplant FS	5 gal.	1 per container	75-100	Requires fertile soil
Kale FS/PS	5 gal.	10-15	55-65	Harvest leaves
Lettuce, leaf PS	1/2 gal	4-6	30-35	Harvest leaves
Mustard greens PS	1/2 gal.	4-5	35-40	Several plantings, two-week intervals
Onions FS/PS	1/2 gal.	2-3	70-100	Require lots of moisture
Peppers FS	2 gal.	1 per container	110-120	Require hot weather
Radishes FS/PS	1 pint	1	25-35	Several plantings, weekly intervals
Squash FS	5 gal.	1 per container	50-60	Plant only bush type
Tomatoes FS	5 gal.	1 per container	55-100	Stake and prune or cage
Tomatoes, cherry FS	1 gal.	1 per container	55-100	Helps to stake and prune
Turnips FS/PS	3 gal.	2-3	30-60	Harvest leaves and roots

* Consult seed catalogs for varieties adapted to container culture.
** FS=Full sun; FS/PS= Full sun, tolerates part shade; PS=Partial shade

Table 2 – Information on Growing Vegetables in Container

More detailed information on each plant requirements can be found at:
http://www.caes.uga.edu/applications/publications/files/html/B1011/B1011tables.pdf

Appendix D – Design for Accessibility (Barrier-Free Design)

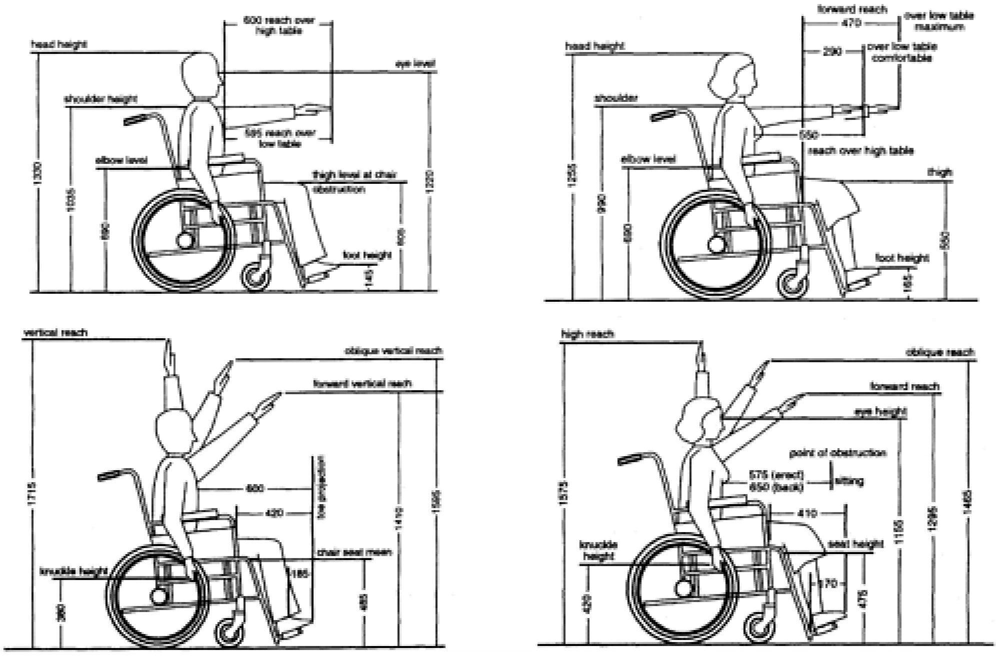


Figure 9 – Reachable distance by disabled males and females confined to wheelchair. [85]

City of Toronto Accessibility Design Guidelines

Although building outdoor areas such as rooftop spaces and balconies are not explicitly mentioned in City of Toronto Accessibility Design Guidelines [86], similar considerations apply.

Some applicable guidelines are as follow, with commentaries:

- 1.3.11 Picnic Area: The picnic table can be considered as container or planter for farming
- 2.2.2 Corridors and Hallways
- 2.3.6 Lockers and Baggage Storage: The maximum and minimum reachable height should be considered when raising the growing bed for people with disabilities to manage it easily.

Appendix E – Minor Stakeholders

Food banks

Food banks are important stakeholders in the food security field. However, we chose to focus on urban agriculture. Thus, food banks are only minor stakeholders, as they do not usually participate directly with food production, but could benefit from it. Food banks might be interested in this project as it can help them to meet demand when demand for food is high. According to Daily Bread Food Bank, the number of visits to the food banks is highest during September when school reopens, and during January and February after the long winter break [18]. There are also reports that accuse food banks for being the obstacles in fighting poverty and hunger as they create the illusion that nobody goes hungry, while limiting household to once-in-a-month hamper. [18]. Improved urban agriculture can increase the supply available to food banks (e.g. through charity community gardens), which can allow the food banks to make more frequent distributions.

Canada Governmental Agencies

At the federal level, the government might be concerned about the design of a method to improve food production in urban setting. There are a few agencies overseeing different codes and standards related to food production. Health Canada is responsible for accessing Canadian Food Inspection Agency's activities related to food safety [87]. This is to ensure a safe and nutritious food supply, which is essential for the health of Canadians [88]. Codes that might be relevant to urban agricultural in an apartment setting are: the Code of Practice of Minimally Processed Ready-to-Eat Vegetables [89], that aims to prevent microbial pathogens associated with *Listeria monocytogenes, Salmonella spp., Shigella spp., E. Coli,* hepatitis A , etc. [89]; and Code of Practice for the Hygienic Production of Sprouted Seeds [90], that aims to prevent microbial pathogens such as *Salmonella spp.* and *E. Coli* O157:H7 [90].

Students and Division of Engineering Science

The Praxis II showcase attracts visitors from industry, government, academia and the general public [91]. In addition, it is covered extensively by the media [91], creating broad exposure to the solutions demonstrated. Relevant stakeholders might be among the exposed audience, and their views (and possibly embracing) of a solution, and those involved in its design depend greatly on the quality of its presentation.

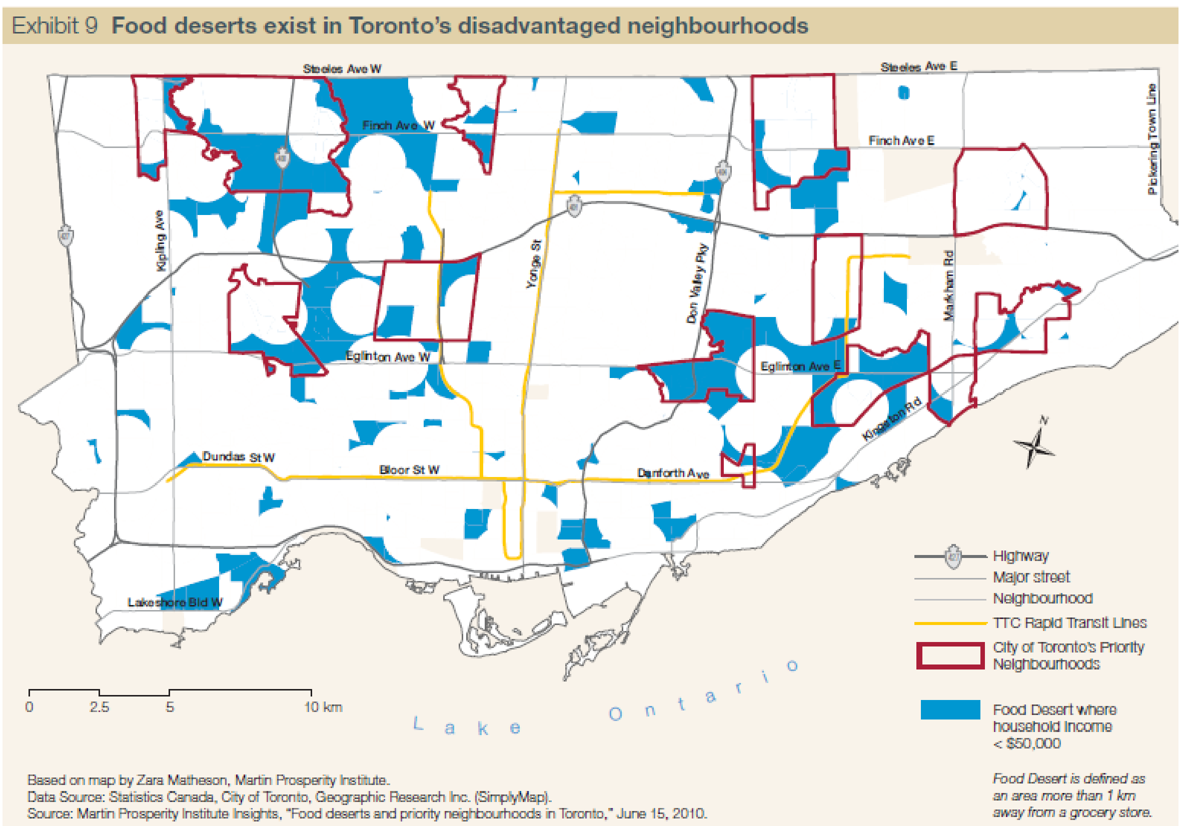
Given the broad exposure, the showcase is an opportunity to demonstrate the Engineering Science students' abilities. As such, it should also be viewed as a public relations opportunity that can contribute greatly to the Division's exposure and attraction of high quality applicants, to the reputation of Engineering Science graduates in general and to individual students' exposure to key players in their fields of interest.

To achieve these goals, the solutions provided should be impressive, innovative, and demonstrable to the media and visitors to the Praxis II showcase, which will likely take place in the Bahen Centre for Technology.

Appendix F – Food Transportation and Food Access Barriers

Wayne Roberts, Manager of the Toronto Food Policy Council, indicated on his blog that a typical food serving is the result of 13 trips to deliver the food from the producer to the end consumers [92], such as, obtaining fertilisers, transportation of farm inputs, immigrating farmers from town to grow fruits, sending food to factories for processing, getting materials for food packaging, transportation of food to distributors, transportation used by consumers to buy food from supermarket, etc.

The amount of transportation required for consumers to travel in order to obtain food is a concern in what are called "food deserts" (see appendix A), where users have difficulties accessing local food stores or community gardens to obtain fresh food [57].



[57]

Figure 10: Areas that are identified as food deserts in Toronto

According to Daily Bread Food Bank, the transportation barriers faced by the food bank users in Toronto are [93]:

- Cost of owning a car (24% users affected)
- Cost of public transit (59% users affected)
- Lack of access to transit stop or subway station (5% users affected)
- Physical barriers such as disability (13% users affected)

- No barriers (21% users affected)
- Other (6% users affected)

By promoting urban agriculture, transportation barriers can be eliminated and excessive cycles of food transportation can be minimized, thus reducing the cost of the food and improving the environmental sustainability of the food system.

Appendix G – Relevant Codes and Standards

Note that the codes and standards mentioned in this section merely serve as a brief guide, and is not the complete list of all codes that are relevant. In any cases of ambiguity or doubt, engineering judgement is required and the actual codes and standards must be referred to ensure safety of the design.

Ontario Building Code

Building codes that are relevant to this design project can be found in Division B, Part 3 (Fire Protection, Occupant Safety and Accessibility), Part 4 (Structural Design), Part 5 (Environmental Separation), Part 7 (Plumbing), Part 9 (Housing and Small Buildings), Part 12 (Resource Conservation). [28]

Toronto Municipal Code Chapter 492 Green Roofs

Any design involving the use of rooftops that fits under the City of Toronto's definition of green roof should comply with Toronto Municipal Code Chapter 492 Green Roofs. [95]

Toronto Green Roof Construction Standard Supplementary Guidelines

For urban agriculture pertaining to rooftop gardening, the design should comply with Toronto Green Roof Construction Standard Supplementary Guidelines. The key aspects discussed are (1) Definitions and Green Roof Components, (2) Structural, (3) Safety, (4) Waterproofing, (5) Vegetation Performance, and (6) Quality Assurance Activities. [96]

ASTM standards The use of material in this design project should follow the relevant testing procedures as specified [97]:

- Installation of roof systems or roof membranes: ASTM Standards Section 4 (Construction) Volume 04.04 (Roofing and Waterproofing)
- Use of wood material: ASTM Standard Section 4 (Construction) Volume 04.10 (Wood)
- Use of plastic material: ASTM Standard Section 8 (Plastics) Volume 08.01 (Plastics I), Volume 08.02 (Plastics II) and Volume 08.03 (Plastics III)

Appendix H – Community in Need

We have identified at least one example for a community in need, which operates a community garden and can be a good pilot project. However, at the time of finalizing this document we did not receive this community's consent to be included explicitly by name. Following Assignment guidelines section *Stakeholders - A specific City of Toronto Community-in-need*: "...without being overwhelmed with requests for resources and information," we did not include any details that would identify this community. This community is a publicly owned group of buildings that operates a community garden, which is categorised as low-income community, defined by Statistics Canada Low Income Cut-Offs (LICOs) [98].

The map below shows the percentage of family renters in high-rise apartment buildings (five storey or more) that were categorized as low income by neighbourhood in year 2006 [99].

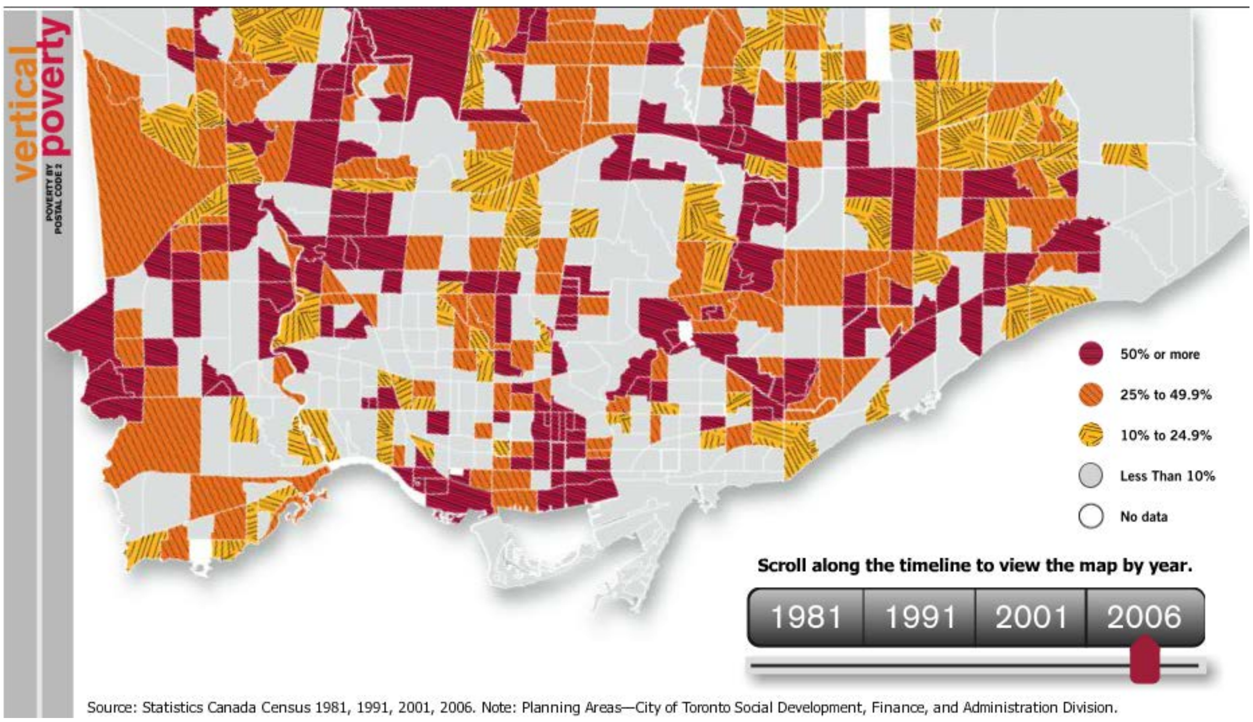


Figure 11 – Percentage of family renters in high-rise apartment buildings (five storey or more) that were categorized as low income by neighbourhood in year 2006

The map below shows the apartment buildings in Toronto, including the red lines that indicate existing and proposed rapid transit, while the red circles indicate confluence of modern tower with rapid transit. [11].

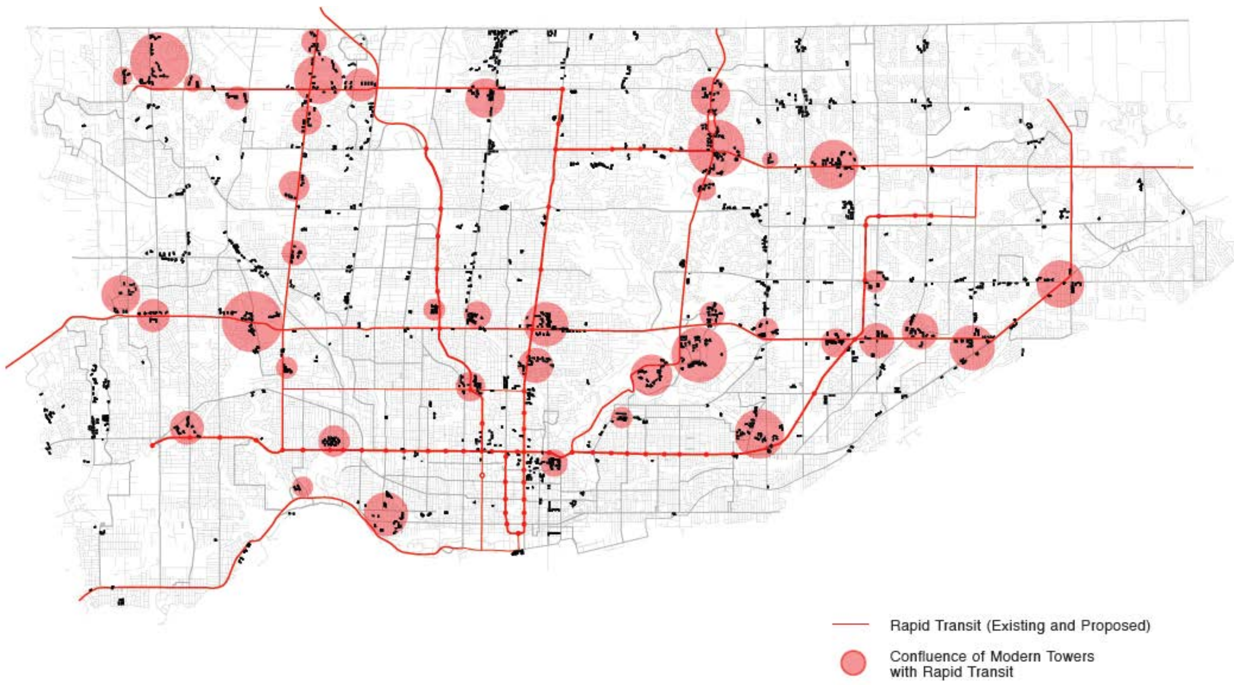


Figure 12 - Apartment buildings in Toronto

Appendix I – Requirements Checklist

The following is a combination checklist and Pugh chart that can be used in evaluating design candidates. The top of the chart consists of the constraints, and is a checklist. The following section concerning the criteria can be used as a Pugh chart.

Solutions	**1**	**2**	**3**	**4**
Constraints				
Adheres to all relevant building codes	☐	☐	☐	☐
Designed for ease of transportation and relocation	☐	☐	☐	☐
Demonstrable for evaluation in a showcase setting	☐	☐	☐	☐
Soil depth> 20 cm	☐	☐	☐	☐
Food available > 40% of the year	☐	☐	☐	☐
Flame spread rating < 75	☐	☐	☐	☐
Plastic materials have a UL94 fire resistance rating of V0	☐	☐	☐	☐
Ratio of allowable load to the maximum loading induced >2.0	☐	☐	☐	☐
Total operating lifetime >1 year	☐	☐	☐	☐
Start-up cost < $100/person	☐	☐	☐	☐
Annual operation costs < $120 per person per year	☐	☐	☐	☐
Cost of one kilogram of food < $2/kg	☐	☐	☐	☐
Is fully compliant with the city of Toronto Accessibility Design Guidelines	☐	☐	☐	☐
Criteria				
Gross annual food production				
Space efficiency of the solution				
Variety of food that can produced				
Growing season				
Mould resistance of materials used				
Child safety				
Flammability of materials				
Flammability of plastic components				
Loading on structure				
Risk of moisture damage				
Dependence on municipal water supply				
External energy consumption				
Recyclability of materials				
Easy to clean				
Longevity of the solution				
Knowledge barrier for use				
Time efficiency				
Start-up cost				
Long-term cost				
Cost efficiency				
Accessibility of the solution				

Table 3 – Requirement Checklist

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