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WOMEN'S RESOURCE SOCIETY

ONEESAN CONTAINER HOUSING PROJECT

JTW Consulting

Report Prepared for:
Atira Women's Resource Society

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Thank you to our Funding Partners without whom this innovative development would not have been possible.

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Part 1 - Introduction

This report provides an overview of the approach taken to up-cycle obsolete shipping containers for residential housing from conceptualization to completion. The report describes the design, technical, cost and approval elements of developing the innovative Oneesan[1] prototype project within the City of Vancouver, British Columbia.

Background

In August 2013 Atira Women's Resource Society cut the proverbial red ribbon celebrating the opening of their brand new, visually stunning recycled shipping container housing development. Building the first multi-dwelling containerized housing project in Canada was no easy feat however and required tremendous commitment, visionary thinking and a huge leap of faith on the part of Atira and its funding partners.

The concept of utilizing used shipping containers for housing typically conjures up appalling images of transporting marginalized people from one hell hole to another and obstinate opinions about housing the poor in warehouse-type facilities. Take a trip to visit this project nine months after occupancy however and you will meet a group of highly satisfied women beaming from ear to ear and extremely pleased and proud to live in their hip, environmentally friendly and award-winning homes located in Vancouver's Downtown Eastside Japantown neighborhood.

Winner of the Real Estate Foundation of BC's 2014 Land Award for the non-profit sector and two prestigious Georgie Awards, Oneesan has also been recognized as innovative and sustainable by industry peers and the British Columbia design and construction community.

Redefining Perception

Stepping back from the stereotypical view of container housing and with a bit of lateral thinking, what looks like a ravaged old shipping container is actually an ideal and ready-made modular superstructure and building exoskeleton.

Made from extremely durable Corten[2] steel, containers with their inherent form, weathering properties and shell-like characteristics make instant walls, floors and roofs. Upcycling obsolete shipping containers is the ultimate in sustainability, using far fewer materials, less construction waste and far less embodied energy over many conventional forms of construction.

Sustainability and durability is becoming a political and financial asset as global environmental concerns gain pace and government subsidized funding becomes inadequate and scarce.

[1] Oneesan in a Japanese word for "older sister".

[2] Cor-Ten® is a brand name for corrosion resistant products that were developed by United States Steel.

Project Overview

In addition to providing much-needed non-market housing in Vancouver's Downtown Eastside, the Oneesan container development was conceived as a prototype pilot project aimed at exploring alternatives to existing housing forms with an emphasis on providing sustainable, durable, cost efficient and high-quality, functional housing.

The emphasis on identifying pilot project outcomes was focused on analyzing and reporting on the following core items:

1. Design & Form
2. Livability
3. Approach
4. Development Phases
5. Construction Methodology

Design & Form

The use of shipping containers as the basis for habitable structures has been developed and explored throughout the world.

These "symbols of globalization" are relatively inexpensive, standardized, structurally sound and in abundant supply.

In raw form containers are dim hulking boxes but technically they can be highly customizable modular elements of a larger structure.

The core design intent for Oneesan was to challenge stereotypical, (and sometimes justified) views on containerized housing as sub-standard, bland and abject living accommodation only fit for temporary housing in developing parts of the world.

Oneesan's exterior design aesthetics focused on retaining the inherent contemporary square like characteristics of the containers.

Texture was created by marrying the articulated Corten steel corrugated panels with opaque glazing panels and accented dashes of rich, clear-cedar horizontal siding and soffit.

A vibrant colour palette gives a nod to the containers former life on the high seas and in dockyards throughout the world.

The Corten steel corrugated exterior shell provides texture and depth while the contemporary elements transform typically stigmatized non-market housing from benign and dull into exuberant and dynamic.

Old-growth fir, salvaged from the original heritage house located on the site, and clear cedar were used to accent exterior doorways and principal elevations to soften the industrial containerized form, as well as to pay homage to the heritage of the area, once abuzz with saw mills and logging yards synonymous with the early industrialized and urban development of Vancouver.

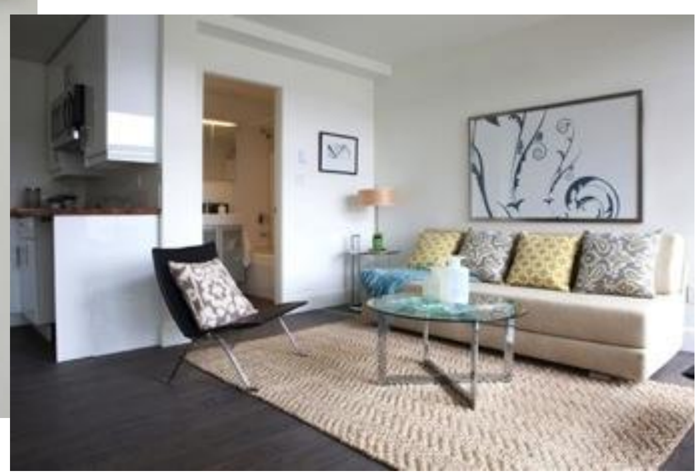
Livability

Based off the sustainable ideology of “Small Footprint - Large Living Area” the Oneesan units consist of approximately 290 sq.ft of net living space intended for tenants who are able to live independently in a micro compact self-contained dwelling unit. Units are studio type with a full bathroom, kitchen and in-suite laundry.

The kitchen accommodates a full-size sink; four-ring ceramic cooktop; a combination microwave, convection oven and exhaust fan. In-suite laundry consists of an under – counter, combined vent-less washer / dryer, more commonly found in Europe.

Air quality of the units is controlled by a combination of natural cross ventilation and a continual low-flow operation bathroom exhaust. Natural light is greatly enhanced by the use of floor to ceiling glazing and space volume has been created with use of nine-foot high ceilings.

Flooded with both artificial and natural light, the units consist of a warm colour palette and the metallic exterior door pops and adds layers of texture and dimension to the small compact floor space.



Livability Survey

A post-occupancy livability survey was conducted with the intent to provide tenants with an opportunity to comment and provide feedback on the livability and functionality of their new container homes. The results of the survey tabulated below show that overall tenant satisfaction is 92% based off a range of livability and unit-performance questions. (See Appendix C – Post Occupancy Survey Forms)

Tabulated Survey Results

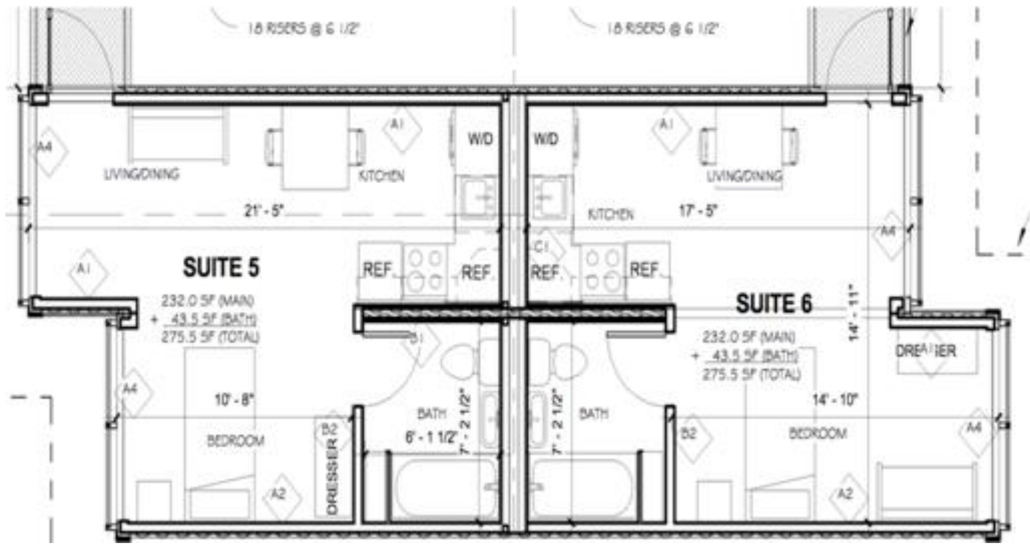
Livability Survey Questions	# Completed	Positive Responses	Negative Responses	Satisfaction Rate
Are the units large enough to live comfortably?	9	7	2	78%
Is the kitchen sufficient for cooking healthy meals?	9	9	0	100%
Is there sufficient ventilation when cooking?	9	8	1	89%
Are the bathrooms sufficient for personal care?	9	8	1	89%
Is heating sufficient in the winter?	9	9	0	100%
Are units cool in the summer?	9	0	0	No Data
Is there a lot of loud noise from adjacent suites?	9	7	2	78%
Is there sufficient natural light from the windows?	9	9	0	100%
Do you feel safe and secure in your unit?	9	9	0	100%

Quotes from Residents

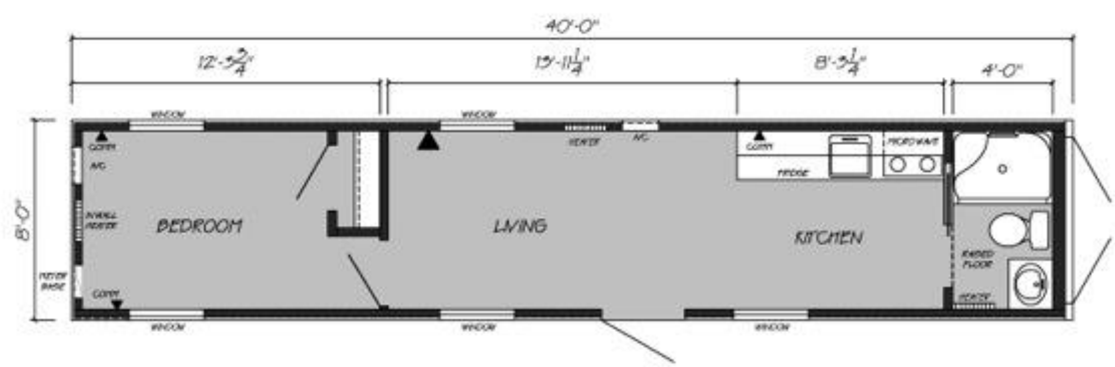
> "The kitchens are set up well and I love the space. It is a beautiful kitchen".
>
> "The natural light is beautiful and is a beautiful feature of the suite".
>
> "This is an extremely quiet building, so much so it can be a little eery".
>
> "This is an extremely safe building, gates, locks, security cameras, lighting, staff next door, neighbors. It's a gem in the DTES".

General comments included with the survey forms will be included in design considerations for future container-housing designs and development.

A typical unit consists of rectangle 16' X 20' floor plate which was constructed using two side-by-side 40' x 8' containers divided in the middle with a fire-rated, suite-separation partition.



Although it would have been more cost and time efficient to create the dwelling units by utilizing a complete 40' x 8' container, it was decided that livability would have been seriously compromised in a narrow 40' long and 8' wide living area.

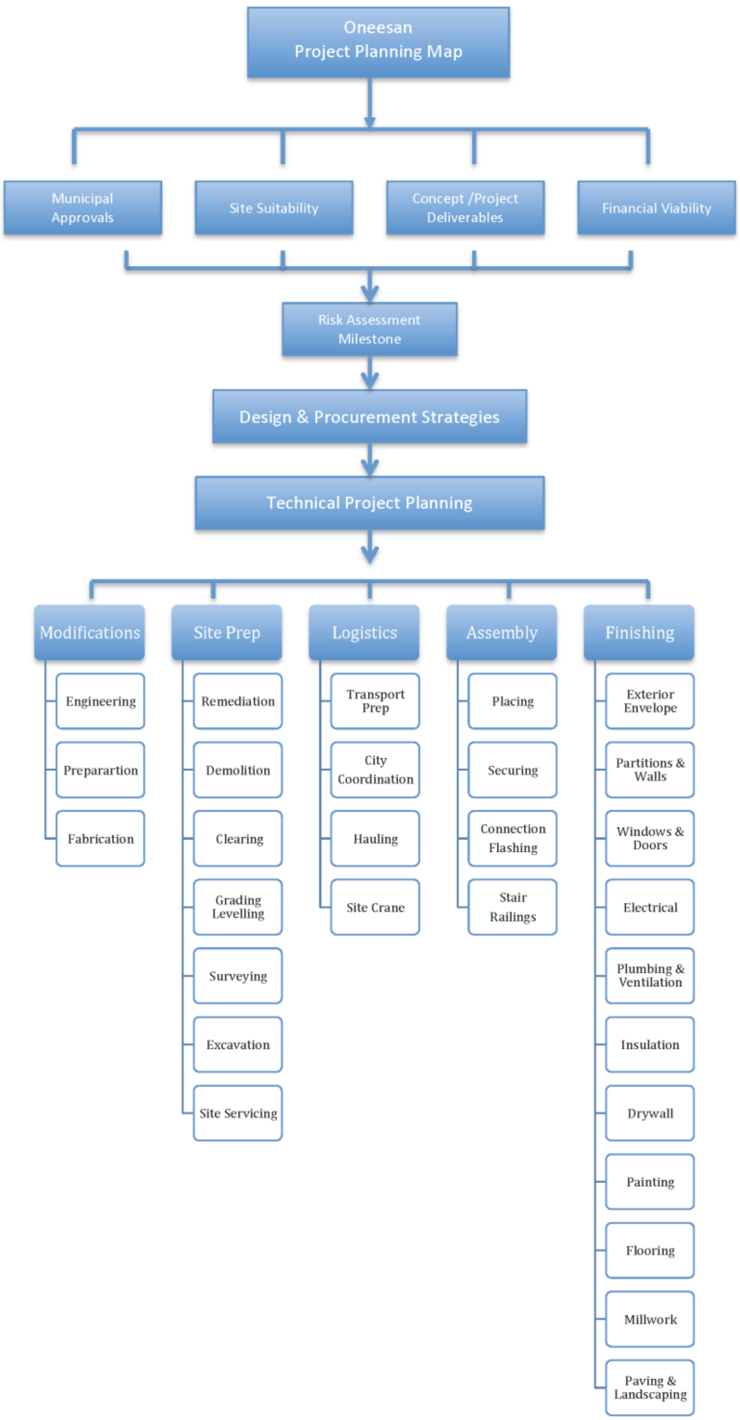


Example of long and narrow 40' x 8' containerized living space.

Oneesan-unit floor plate using two, side-by-side, 40' x 8' containers, divided in the center with a suite-demising wall.

Project Planning

To successfully execute the development of the innovative prototype Oneesan project, it was identified that a concise and detailed plan was required. The planning flow chart below provides an overview of the Oneesan project's planning methodology and development implementation strategy.



Approach

The idea of converting retired shipping containers to housing or other structural enclosures (workshops, emergency medical facilities, etc.) is not a new concept. In fact, there is a fairly substantial existing industry offering this sort of conversion commercially.

Many examples of containerized projects however have been built in jurisdictions were planning and building code requirements are not applicable or limited. For example, the highly-regarded Tempohousing Amsterdam University container housing project was approved and constructed as a temporary development and as such was not subject to the normal planning and technical standards typical in the large Dutch municipality.

In the case of Oneesan, proposed as a permanent residential structure developed within a strictly regulated municipality, it was critical that sequential risk planning was conducted to ensure the project was confirmed feasible and financially viable.

Given the trail-blazing nature of the project, a systematic due-diligence strategy was employed to validate the feasibility of undertaking the development. This approach was particularly important due to the fact that no research and development funding was available and project costs had to be covered with equity contributions and debt financing based on Oneesan's future rental revenues.

The approach to completing the development was therefore to move the project progressively forward through four distinct planning phases. As each phase was successfully completed and assumptions verified and confirmed, a commitment was then made to proceed to the next phase.

This risk-managed approach allowed the project (if required due to insurmountable issues) to be cancelled with the least financial exposure to Atira.

Development Planning Phases

- Due Diligence / Project Feasibility Phase
- Risk Assessment Phase
- Design / Procurement Phase
- Construction Phase

Phase 1 - Due Diligence & Project Feasibility Phase

The success of any project is largely contingent on the amount of due diligence and planning conducted during the inception / conception phase of development. In the case of the Oneesan project, a number of fundamental factors were identified as core determinants to the success of the project.

The core determinants are listed and described below:

Project Deliverables

Site Suitability

Municipal Approvals

Financial Viability

Project Deliverables

Involved clearly defining the purpose of undertaking the challenge of developing Canada's first multi-residential containerized project.

Core deliverables included:

- Research of innovative, cost efficient and alternative housing solutions;
- Challenge stereotypical containerized housing opinions and optics;
- Promote upcycling & sustainability;
- Provision of durable, affordable, quality and livable non-market housing

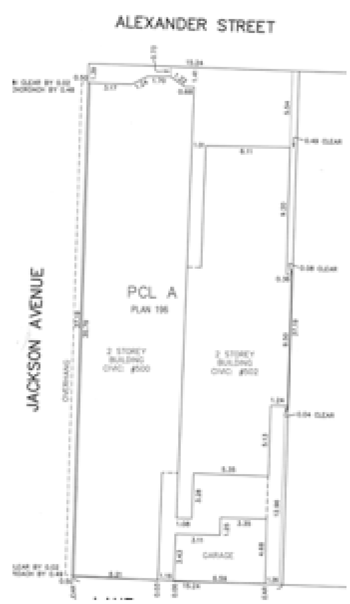
Site Suitability

Involved identifying potential site constraints that could have restricted or deemed the development unworkable. Site suitability included consideration of the following items:

- Site area and dimensions;
- Municipal zoning and development allowances and restrictions;
- Evaluation of adjacent site constraints such as power lines, structures, access and air rights to enable craning and placement of container units

The Oneesan housing development was developed on an elongated 25' x 117' site and sandwiched between two existing single-room-occupancy properties, typically referred to as SROs or rooming houses.

Proposed site sandwiched between existing buildings

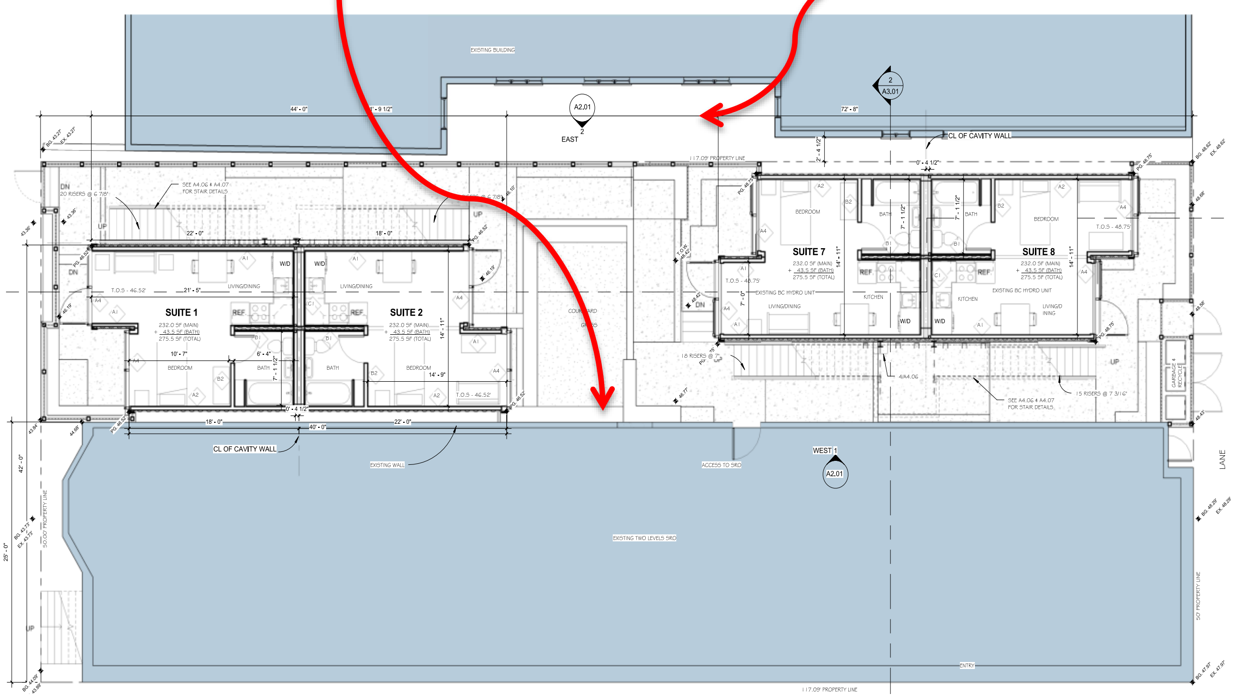


The adjacent properties were built during the early 1900's when light/window wells built adjacent to internal lot lines provided natural light and ventilation to occupant rooms located in the central section of the 117' long building located on the sites.

As per City of Vancouver planning and building regulations, any development on the project site was required to respect and consider the neighboring buildings and their occupants.

This translated into setbacks from adjacent light wells to avoid obstructing and oppressing tenants living in adjacent suites, open space allowances for natural light to illuminate the central sections of both the proposed and existing properties and to provide for fire and life safety measures.

Containers set back to respect adjacent neighbors and allow natural light to light well windows and new courtyard.



Regardless of the form of development the above constraints apply to all types of construction including traditional timber stick built, concrete or steel framed and resulted in a requirement to build on a restricted tight footprint within the existing site.

The requirement to allow natural light and unobstructed outlooks for adjacent tenants also greatly influenced the need to build and service two separates container buildings on the site, which from a cost perspective is not the most efficient approach to development.

Given the described site-specific constraints, the modular standardized size and noncombustible material of the containers resulted in an apt and relatively efficient application for this particular development.

Municipal Approvals

The Oneesan project was required to meet a number of municipal bylaws including planning guidelines, zoning regulations and building-code controls. From a planning and zoning perspective, the utilization of containers involved similar area, height, density and form / character considerations as a typical development using traditional forms of construction.

Building code controls impose a set of prescribed performance standards for the construction of buildings and their ability to meet minimum fire safety, health, material and building system provisions.

Building code provisions have been predominately developed with consideration to the historical performance of traditional and typical construction techniques, assemblies, materials and systems.

Confirmation that the project could achieve code was identified as a major potential constraint that could jeopardize the feasibility of the innovative pilot project and as such priority was given to conducting a thorough and detailed building code review.

A strategy of initiating early discussions with City building approvals staff was also adopted for the dual purpose of confirming code assumption and to provide the City with assurances that using modified recycled containers for housing was feasible from a code perspective.

Even though containerized housing is generally considered an innovative and ground-breaking approach to construction, applying and achieving the code provisions with respect to fire safety, health, material and building systems from a technical perspective was relatively straightforward.

Financial Viability

As with any project the Oneesan development was required to be confirmed financially viable with the development of a project-specific proforma. To establish initial and conceptual project costs for research, design and construction, a preliminary scope of work was developed and then budgeted.

The project's preliminary budget also needed to consider Vancouver's high-cost microeconomic environment and compare to traditional construction industry cost benchmarks (adjusted for small unit / floor plate cost inefficiencies).
Notwithstanding the prototype innovation, where there was a significant learning curve to climb and navigate, a per-unit target cost benchmark was established based at one third of the cost of a similar unit of government funded and built non-market housing.

It was subsequently determined from historical costs for projects operated by Atira under a government-funded / built program that non=market housing units built in 2011 cost in the range of $200 / 250k (hard construction costs).

The outset financial target was therefore to significantly reduce the cost of comparative non-market housing and attempt to establish containerized hard construction costs within a range of $80 – 100k per unit. (See Part 2 – Cost Analysis a detailed overview of project costs).

Phase 2 - Risk Assessment

The information assessed during the risk assessment phase was developed during Phase 1 - Due Diligence & Project Feasibility.

Risk assessment, in the context of pre-construction activities and planning, involved conducting a detailed evaluation of preliminary technical, financial and bureaucratic assumptions as well as a review of any physical constraints related to logistics, modifications and site conditions that had the potential to jeopardize the project.

A pragmatic approach was developed to prioritize project activities – by cost ramifications, potential approval issues and technical constraints - to determine risk and plan mitigation to allow the project to move forward.

The following are examples of the prioritization and evaluation of project risks:

- Effects or limitations adjacent properties would impose on utilizing the site;
- Efficiency of siting modularized containers with fixed dimensions on the site;
- Ability to access the site for container hoisting, placing and assembly;
- Ability to meet zoning and municipal planning requirements;
- Ability to adapt and modify containers to meet building code requirements;
- Ability to develop technical solutions to address non-conforming code provisions;
- Ability to develop technical expertise to modify and construct the project;
- Ability to develop accurate modification and construction budgets;

Phase 3 – Design & Procurement

Phase 3 tasks focused on developing the initial schematic designs to permitting, tender and working drawings and establishing an appropriate procurement methodology.

Although the project could have been classified as a Part 9 building under the VBBL (Vancouver Building By-law), it was designed professionally under the more restrictive Part 3 of the code. Designing under Part 3 of the VBBL was a risk management initiative to ensure the City's building permitting department approved the project.

Efficient procurement of work by utilizing the most suitable procurement strategy has long been considered a major determinant of project success; therefore the preferred procurement methodology needed to be carefully considered as the building was technically unique with a potentially high risk of scope creep. Scope creep typically equates to additional costs and longer project scheduling.

Design-tender was considered too rigid as 'fixed' lump-sum prices typically need to be obtained before construction can commence. Given that Oneesan was a prototype innovation there would have been a significant risk premium added by the General Contractors for unknowns.

It was also recognized that there would be an element of technical evolution during the construction phase that was not possible to communicate in design contract documents issued for tender.

Given the pragmatic and evolved nature of constructing Canada's first major containerized project, a flexible and open procurement methodology was preferred.

Construction Management 'as Agent' (CM Agent) was therefore evaluated and chosen due to the ability to sequentially tender sub-contact work and make changes without major penalty and with the use of own forces.

Phase 4 – Technical Scoping & Planning

Container Modifications

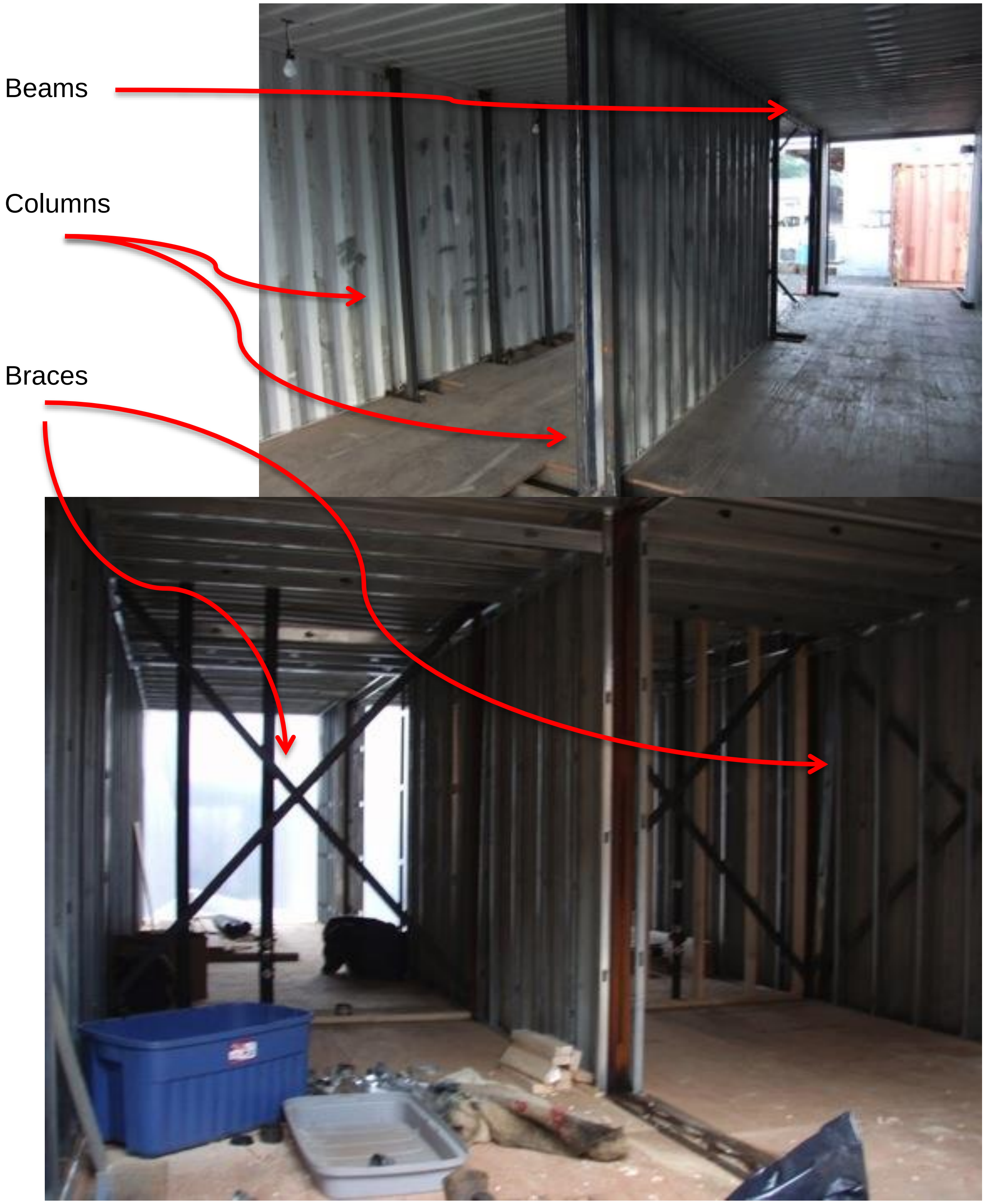
There is probably a misconception that shipping containers can simply be picked up from the dock side and dropped on to a building site to be used as building's superstructure and exterior shell.

While shipping containers have monocoque bodies and their corrugation panels (roof, sides, and back), floor, purlins, front doors, frame and rails form an integrated structural skin, once they are modified to create openings and open spaces they are weakened and require structural modifications.

In the case of the Oneesan project modifications were required: to open up larger floor areas; install services; attach exterior elements such as the roof structure; curtain wall system; stairs; and balconies.

Stairs & Landings

Modifications included adding structural components such as columns, beams braces, and shims



Openings modified to install curtain walling

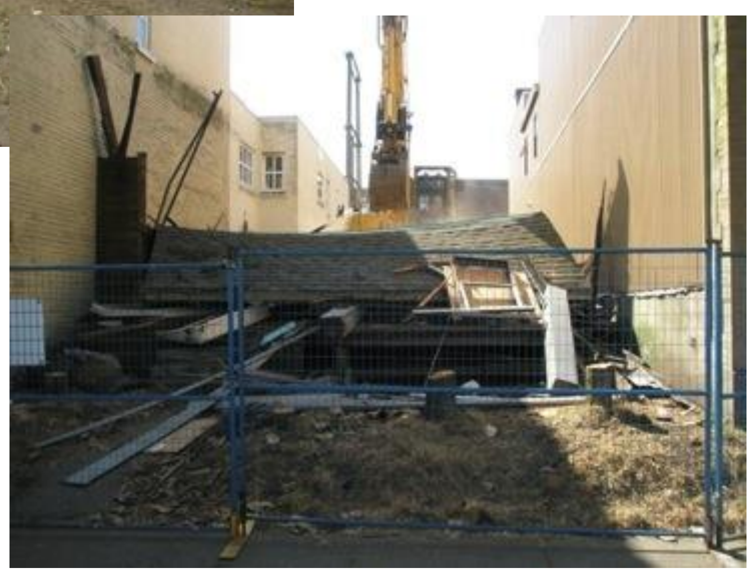
Stairs – Landings – Flashings – Openings

Modifying the container also required a significant amount of engineering to meet seismic / wind loads for code, design coordination and fabrication such as steel cutting and welding.

Site Preparation

As with any building constructed in a regulated jurisdiction, the Oneesan project site had to be properly prepared, serviced with utilities and connected to municipal systems such as water, sewage, storm water runoff and below grade drainage.

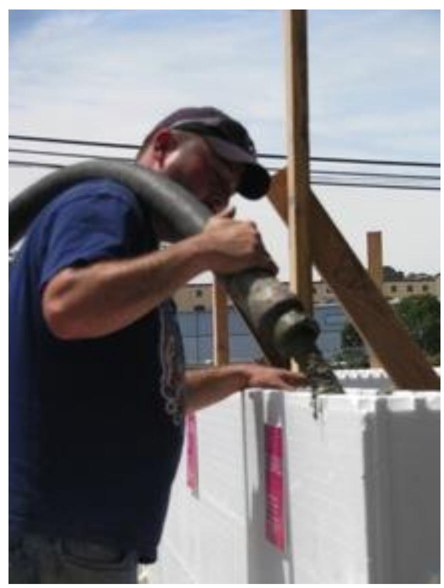
Site preparation consisted of remediation of hazardous materials, demolition of an existing structure, tree removal, debris clearing, grading / leveling and final excavation and surveying for the building's foundation system.



Foundations

A simple below frost 20' x 10' strip foundation with a heated / ventilated crawl space was constructed to support and carry the container loads.

Foundation walls were formed using an ICF system (Insulating Concrete Form). The expanded polystyrene (EPS) forms are interlocking modular units that are dry-stacked and filled with reinforced steel and concrete. The forms lock together somewhat like Lego bricks and serve to create a form for the structural walls and floors of the containers.



ICF technology is a green and sustainable building system that delivers a foundation wall that is highly energy efficient, structurally tough and provides superior sound suppression. ICF construction cuts down on landfill waste over traditional lumber forms and is fast and easy to install.

Site Servicing

Logistics

Given the magnitude and requirement to transport, store and handle bulky and heavy containers during fabrication it was necessary to conduct the necessary modifications offsite at a facility with the capacity and equipment capable of managing the logistics of modifying, moving and storing up to twelve 40’ x 8’ containers.

The coordination of hauling twelve modified containers to the construction site and then craning them into place over an existing building within one day was a major logistical challenge, which required traffic control and City street closures.

Modified Containers Transported to Site

Containers craned over existing buildings

Assembly

Once modified the containers were transported to the prepared site (foundations) and then craned and stacked and placed onto steel connection plates previously installed in the foundation wall. Once placed the final fabrication work was completed to tie down and weld the containers together.

Construction Methodology

Exterior Envelope

The exterior envelope utilized the existing corrugated container shell with glazed openings for natural light and ventilation. A rain screen system is typically required in Vancouver however with an engineered approach it was determined that the inherent characteristics and properties of the existing Corten steel shell did not necessitate the need for an additional exterior rain screen system.

Envelope Components

Roofing — SBS modified bitumen 2-ply system - This system is ideal for low slope type-roofing applications and utilizes a top ply of granulated modified bitumen and 1 ply of smooth modified bitumen.

The roofing membrane was applied to a 'cold' type wood framed roofing structure consisting of joists, rim beams and headers. The roof was cross-ventilated with the use of purlins installed perpendicular to the main roofing joists.

Roof Framing

Soffit Framing

Exterior Walls

Exterior walls are constructed of Corten steel. Corten is included in a group of metals known for their properties to weather. "Weathering" means that due to Corten's chemical compositions, it exhibits increased resistance to atmospheric corrosion as compared to other steels.

This is because the steel forms a protective layer on its surface under the influence of moisture.

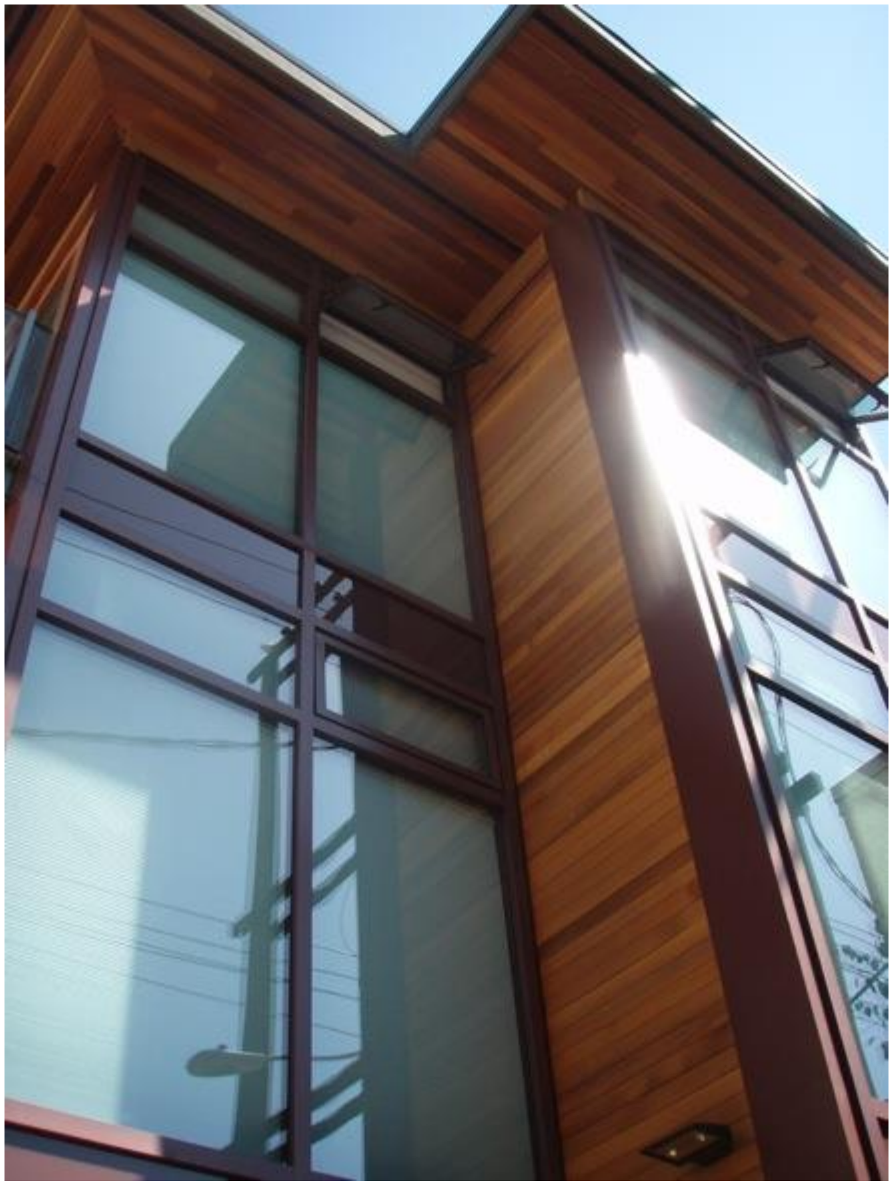
Corten Steel Exterior Walls

The corrosion-retarding effect of the protective layer is produced by the particular distribution and concentration of alloying elements in the Corten steel.

The layer protecting the surface develops and regenerates continuously when subjected to the influence of the weather. In other words, the steel is allowed to rust in order to form the 'protective' coating.

Curtain Wall

A curtain wall system was used to create glazed elevations with openings to allow for natural ventilations. To create openings for the installation and support of the glazed walling system, the container units' doors and rear panels were removed.



Installing Curtain Walling

Doors

Doors are standard insulated metal installed and weatherproofed with appropriate caulking and custom designed metal flashings.

Siding

Cedar siding was added as a texturized aesthetic accent and does not contribute to the performance of the exterior envelope to withstand weathering and moisture ingress.

Soffit

Cedar soffit with a perimeter ventilation strip system was used to add aesthetic texture and provide cross-flow roof ventilation.

Penetrations

Service penetrations for exterior exhaust, lighting, fire alarm, emergency lighting and power outlets were terminated with appropriate caulking and custom designed flashings.

Base Flashings

The connection between the container and foundation walls required special attention due to the design of the container bases and the need to provide level access into the units. A waterproof connection was therefore created with the use of appropriate caulking and custom metal flashings.

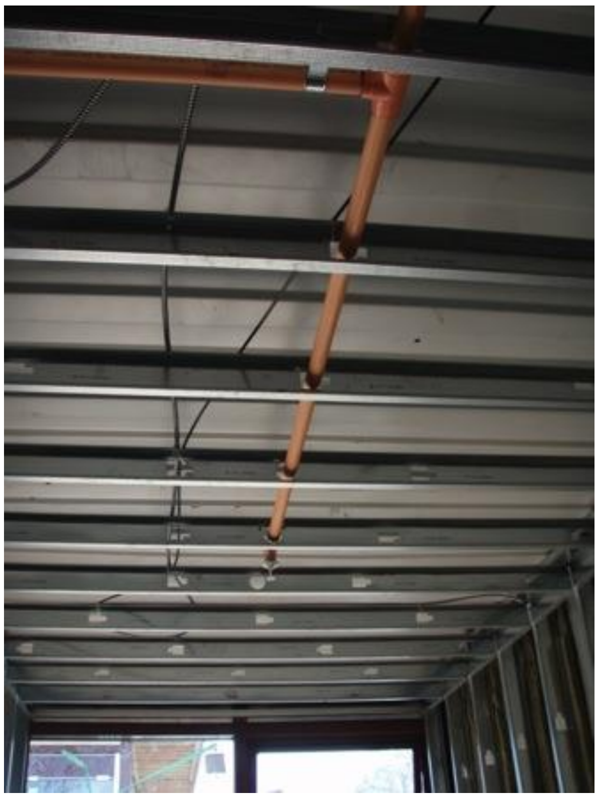
Internal Systems & Finishes

A project objective was to create a living unit that once inside was considered typical and comparable to similar market type accommodation.

An overarching goal was to use shipping containers to create a distinguishable building structure but with a conventional living space.

Partitions, Walls & Ceilings

Partitions, walls and ceilings were constructed using light gauge steel studs.



Although wood studs would have been more cost economical the proximity to adjacent and subsequent code provisions dictated a need for certain exterior walls to be constructed of noncombustible materials

Using steel was also advantageous in improving over-all quality of finish, durability and to significantly reduce construction landfill waste.

Insulation & Sound Proofing

To enhance and increase the energy performance of the project, closed cell spray foam was used in exterior walls and roofs. Closed cell spray foam insulation is a one-step performance material which both insulates and air seals the containers.

Ceiling Insulation

Wall Insulation

There are considerable advantages to using closed cell, as opposed to the commonly used fiberglass batt insulation as shown in the table below:

Insulation Comparison Chart

Desired Features	Closed Cell Spray Foam Insulation	Fiberglass & Cellulose Traditional Insulation
Thermal comfort and R-Value.	✓	✓
No harmful long-term emissions	✓	✓
Material air-seals insulated cavity without extra sealing and labor	✓	
Completely fills irregular or hard-to-reach areas	✓	
Not a source of food for mold	✓	
Won't shrink over time	✓	
Not damaged by water	✓	
No framing distortion	✓	
No settling or sagging	✓	
Minimize airborne sound transfer	✓	
100% water-blown		
Meets requirements for an Environmentally Preferred Product (EPP) CHPS E.Q. 2.2. Compliant	✓	

VBBL-required suite separation soundproofing provision was achieved using Rockwool sound batt installed in the suite demising partitions and ceilings.

Sound batt was also installed in bathroom walls to reduce the transfer of noise (carried by the plumbing systems between suites) and occupant use.

Electrical /Fire Safety

Electrical and fire safety systems were installed in accordance with the VBBL and British Columbia Electrical Code. The units are heated electrically with the use of thermostatically controlled baseboard heaters.

Plumbing & Sprinklers Ventilation

Plumbing was installed in accordance with the VBBL (plumbing code) and Sprinklers to NFPA 13R Standard. Ventilation was installed in accordance with the VBBL and applicable ASHRAE Standards.

Drywall & Paint

Units were finished with two layers of gypsum drywall. The drywall acted as a substrate for paint and also provided the necessary fire-rated membranes required to meet the VBBL fire separation and rated code provisions.

Flooring

A durable laminate flooring finish with sound proofing underlay was provided in living areas. A moisture resistant strip vinyl product was installed in the bathrooms.

Millwork

Kitchen cabinets and bathroom vanity units were installed in suites to create the fully self-contained amenity areas.

Part 2 - Cost Analysis

The following information provides an evaluation of costs to construct the Oneesan Project. The purpose of the cost analysis is to establish a tool and process by which business decisions are analyzed regarding the financial feasibility of undertaking further containerized housing projects. The cost analysis is also intended to provide a comparative cost benchmark against similar projects and forms of construction.

Using the cost data generated in this report and prior to developing further container projects, it is prudent to conduct a cost-benefit analysis as a means of evaluating the viability of utilizing containers.

Containers by their modular characteristics should in theory compliment certain sites better than conventional construction and conversely, conventional construction will have more efficient applications than containers.

In the case of the Oneesan project and its close proximity to existing buildings, requirements for non-combustible construction and efficient use of the site make direct cost comparisons with stick-framed construction, which would typically be used for projects of this size and type, difficult and challenging to compare without detailed adjustments and a comprehensive understanding of the intricacies between both forms of construction.

As an innovative prototype project, there however needs to be a reasonable approach to recognizing inefficiencies and appropriate adjustments made for forecasted productivities if the concept was replicated and expertized technology and knowledge developed.

The cost analysis is also intended to calibrate costs for site specific elements and unique design characteristics that influence calculated cost rates such as site constraints, servicing small sites / floor plates, exterior egress / life safety components. Costs for these factors need to be appropriately digested into gross and net floor area calculations.

Prototype Inefficiencies

Although the Oneesan was required to be developed within Vancouver's microeconomic environment and compared to traditional construction methodology cost benchmarks, as with any prototype innovation there was a significant learning curve to climb and navigate.

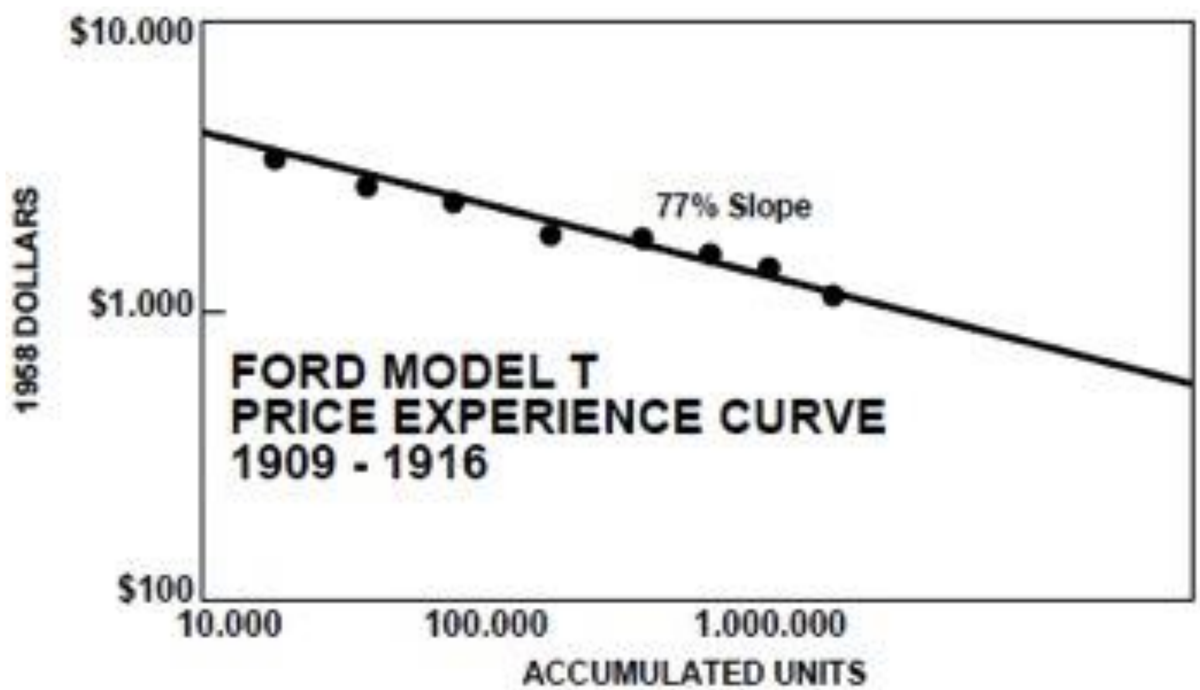
To reasonably evaluate the embodied efficiency of any concept, product or technology, repetition, revision and a "lesson learned" approach is required to allow for the development of sufficient knowledge, expertise, and processes to measure efficiency from a production and future cost perspective.

Learning Curve Theory

There is a scientific ‘learning curve theory’ that states that as the quantity of items produced increases, costs decrease at a predictable rate. It is concerned with the idea that when a new job, process, or activity commences for the first time it is likely that the workforce involved will not achieve maximum efficiency immediately.

Repetition of the task will make people more confident and knowledgeable, which will result in operations that are more efficient. There is a proven and simple graphical representation of how repetition and the ‘learning curve theory’ works as shown with the production of the superlative Ford Model T phenomenon.

Ford Model T Experience Curve



Cost Evaluation

When reporting costs for construction it is important to create a baseline or benchmark cost that enables an apples-to-apples comparison to other forms of construction. In the case of the Oneesan, we have number of project-specific cost influences that make evaluating an accurate and trustworthy cost comparison extremely challenging.

The following cost influences are described below:

Site Profile	Proximity to adjacent property lines and building code requirements determined that exterior walls needed to be constructed from non-combustible materials. This requirement would have constrained the use of timber stick-framed construction typically regarded as the most economical conventional form of construction. A direct cost comparison to timber stick-framed construction is therefore not practical. A hybrid timber / concrete (with its non-combustible properties) form of construction would be more appropriate. Additionally, although 12 units were developed the site profile dictated that two separate six unit buildings had to be constructed. This resulted in an inefficient duplication of site services, building services, exterior stairs and additional roofing and foundation components. Due to site / proximity driven code requirements exterior components such as stairs, landings and guards also need to be constructed of non-combustible construction. This resulted in these items having to be fabricated from premium cost steel.
Project Scale	Regardless of the form of construction it is generally recognized that the scale of project has a significant influence on the efficiency of construction and overall project cost and as dictated by the site profile the project was relatively small at only 12 units, constructed in two separate buildings. Construction costs tend to significantly increase when there is a lack of scale of economies to offset the cost of items such as general conditions for site facilities, management and supervision, site and building servicing and exterior landscaping, fencing and paving.
Small Suites	Constructing 300 sq.ft fully self-contained residential type suites is typically not considered cost efficient from a scale of economies and sq.ft cost perspective. Conversely however, smaller units usually result in lower costs per unit. (See 'small suite' section further in the report). Construction cost guides issued by industry leading cost consulting companies also base reported cost rates off larger scale projects with larger suites and a higher number of units making accurate and representative apples-to-apples comparisons challenging.
Construction	Although the project was constructed from containers it could be classified as a light steel framed building. Buildings constructed from Steel are typically considered to be more durable and used for higher quality commercial / industrial type structures.

Categorizing Oneesan

For the purpose of comparing construction costs the Oneesan project must be categorized against conventional forms of construction and building types. The table below itemizes Oneesan building characteristics and then a comparison is made against conventional forms of construction and building types.

Criteria	Oneesan Results	Comparison Results	
No Units	12 (small suite)	No	(Typical examples between 500 -600 sq.ft)
No Stories	3 (walk-up)	Yes	(Townhouse, Mid-rise apartments, House)
Type of Occupancy	Residential	Yes	
Type of Construction	Non-combustible	Yes	(Concrete / Steel)
Form of Construction	Steel	No	(Steel used for commercial / industrial)
Scale of Economies	Low	Yes	(Single House / Townhouse)

Comparative Cost Examples

The 2014 Construction Cost Guide published by the Altus Group – (see appendix B - Altus 2014 Construction Cost Guide) provides a range of sq.ft cost benchmarks suitable for conceptualizing project costs for similar building types constructed in Vancouver.

The cost benchmarks published in the guide are derived from a sample number of previously constructed buildings where their construction costs have been recorded and then reported. As there are no historical costs for containerized construction the cost guide has been used to develop assumptions suitable for comparing Oneesan's costs against conventional forms of construction and building types.

Altus 2014 Published Cost Guide

RESIDENTIAL CONDOMINIUMS & APARTMENTS	Basic Quality	175	-	215
	Medium Quality	195	-	250
	High Quality	245	-	295
	Point Towers - 50 to 80 Storeys (Medium Quality)	260	-	355
	Point Towers - 50 to 80 Storeys (High Quality)	340	-	450
TOWNHOUSES	Row (Medium Quality)	95	-	115
	Stack (Medium Quality)	115	-	140
	Walk-Up Timber Frame (Basic)	135	-	155
	Walk-Up Timber Frame (Medium)	150	-	175
	Walk-Up Timber Frame (High)	185	-	240
HOUSES	Speculative (Basic Quality)	100	-	165
	Speculative (Medium Quality)	165	-	225
	Speculative (High Quality)	225	-	350
	Custom Built	400	-	1,000

Establishing Suitable Comparisons & Cost Benchmarks

Given the unique characteristics of the Oneesan project it is reasonable to take a hybrid approach in establishing an appropriate comparative building type and cost benchmark. The hybrid approach combines the characteristics and cost ranges for the following building types identified from the Altus Cost Guide:

Cost Group	Oneesan Characteristic	Sub-Group	Cost Range
Residential Apartments	Non-combustible	Medium Quality	195 - 250
Townhouses	Walk-up	High Quality	185 - 240
Houses	Small Scale	High Quality	225 - 350

Based off the approach of comparing the Oneesan project against a hybrid of building types identified in the Altus Cost Guide it is considered reasonable to create a comparative cost benchmark by taking the aggregate of the low and high costs reported in the Guide.

Comparative Cost Benchmark Calculation

	Cost Range
	195 - 250
	185 - 240
	225 - 350
Aggregate Cost Target	241

Oneesan Reported Project Costs

Construction costs for the Oneesan project need to be calculated and reported in order to make a comparison between the comparative cost benchmark of $241. The final expensed hard construction costs for the Oneesan project has therefore been calculated at $1,093,016 (See Appendix B – Oneesan Schedule of Values).

The expensed project cost of $1,093,016 however includes costs that could be considered either site-specific or one-time research and development costs. These costs have therefore been identified and deducted to give an adjusted appropriate reported project cost.

Deducted Costs

The following costs are to be deducted from the final expensed budget. Deducted costs are supported with a brief rationale

Cost Deduction	Value	Rationale
Demolition & Remediation [1]	$44,335	Cost to remediate and demolish a house located on the site
Donated Containers [2]	$33,000	Moving & Storage Fees
	$9,000	Demolition of donated containers
	$8,000	Additional modification costs to adapt Hydro containers
	$3,800	Additional haulage and transport costs to move Hydro Units
Research & Development [3]	$37,157	Concept / prototype development, mock –up fabrication, transportation and project management
Total	$135,292	

Adjusted Budget

Expensed Budget	$1,093,016
Deducted Costs	$135,292
Adjusted Hard Costs	$957,724

Oneesan Reported Project Costs

Hard Construction Costs	**Unit Cost**	**Sq.ft Cost [4] (Total GFA 4380 sq.ft)**
$ 957,724	79,810.28	$218.66

Cost Benchmark Comparison

Comparative Cost Benchmark	$241
Oneesan Costs	$219
Difference	$22

In preparing a "Gross Floor Area " (GFA) the following criteria was applied;

1. Measure each floor to the outer face of the external walls;
2. Measure covered exterior stairs and landing;
3. Include 20% of external walkways dedicated as egress to exits and serviced with fire and life safety system.

[1] Demolition and removal of hazardous materials from existing single family dwelling located on the development site
[2] Olympic games container housing display prototype donated by BC Hydro
[3] Research and development costs that would not be incurred for similar future container projects
[4] Gross floor area (GFA) includes covered stairs, landings, and serviced exit / egress routes

Container Cost Modeling

One of Oneesan's main reporting objectives as an innovative pilot project is to evaluate the viability of developing further container projects of a greater scale with different unit types and sizes. To enable an evaluation of larger container projects a cost modeling exercise has been undertaken using Oneesan reported hard construction costs.

The cost modeling evaluation also includes a cost analysis to compare containerized construction against conventional forms of construction such as timber-framed and concrete developments. In order to compare the Oneesan with comparable convectional developments it is necessary to make a number of assumptions and adjustments to create a level playing field in which to conduct the comparison.

Cost Modeling Methodology

The following describes the methodology employed to develop the cost modeling data required to enable comparisons and review the efficiency of constructing larger containerized development:

1. Establish comparative unit types (studio, 1 bed, 2 bed, 3 bed, & GFA)
2. Describe micro-suite cost inefficiencies when reported on a cost per sq.ft measurement
3. Describe micro-suite costs efficiencies when reported on a cost per unit measurement
4. Calculate 'base unit costs' for Oneesan and then model costs for increased project scale and unit type and area.
5. Conduct comparative cost evaluation against conventional construction forms

Methodology Item 1 - Establish Comparative Unit Type / GFA / Utility

	Unit Type	**GFA**	**Utility**
Baseline (Oneesan)	Studio	365	1 Bath, 1 Kitchen
Model 1	1 bed	685	1 Bath, 1 Kitchen
Model 2	2/3 Bed	1005	2 Bath, 1 Kitchen

Methodology Item 2 - Micro-suite Cost Inefficiencies (when reported on a cost per sq.ft measurement)

It is important to recognize that constructing micro-compact suites from a cost per sq.ft perspective is particularly high when compared to costs published in Construction Cost Guides for conventional forms of construction.

Published costs for market residential apartment type construction for both wood frame and concrete construction are typically calculated from projects of between 40 – 80 units per development with larger unit floor areas, usually with ranges for common unit mixes of 550 – 650 GFA for 1 bedroom and 700 -900 for 2 bedroom units.

Oneesan costs are predominantly influenced by the fact that construction costs for site servicing, sewage, drainage, fire / sprinkler systems, electrical, plumbing distribution, kitchen millwork and bathroom fixtures are divided over a relatively small floor area resulting in a significant increase in overall sq.ft costs.

The examples of construction components and systems mentioned for the purpose of this report are considered 'base unit costs'; meaning that regardless of suite area the cost for these items remain constant. Therefore doubling the area of the suite does not result in doubling of suite costs.

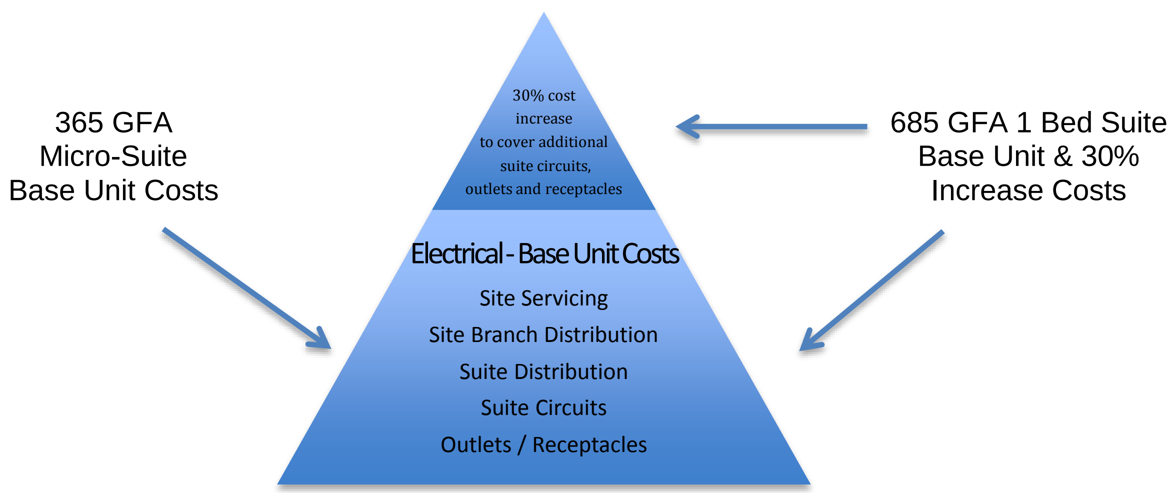
Examples of construction components and systems that remain constant regardless of unit area are listed below:

Component / System	Examples
Site Servicing	Water, sewer, drainage, and electrical systems
Plumbing Distribution	Risers, branch and suite distribution to bathroom / kitchen
Electrical Distribution *	Risers, branch and suite distribution to bathroom / kitchen with a 30% increase above base unit costs due to larger of 285 GFA
Bathroom Fixtures	Bath, Vanity, Shower, Fixtures
Kitchen *	Cabinets, countertop, sink, tiling, with a 30% increase above base costs due to larger floor area
Fire Alarm System	Alarm panel, annunciator, alarm devices, exit pull stations
Sprinkler System *	Sprinkler tree, zone flow devices, sprinkler risers, distribution with a 30% increase above base costs due to larger floor area
Glazing Systems	Curtain walling, windows
Entrance Door	Main suite door and hardware

For a limited number of construction components listed above it is reasonable to apply a 30% cost increase for servicing additional floor area for the larger units. Cost increases are appropriate for systems such as electrical and sprinkler as well as building components such as kitchen millwork where increased floor areas result in additional service coverage and required functionality.

Using the electrical system as an example, when constructing a larger unit there will be a proportional cost increase for running additional circuit wiring within the unit to service outlets and fixtures, but the majority of the base cost for site infrastructure and primary unit distribution will remain constant.

Example of applying the 30% cost increase to cover additional electrical suite circuits, outlets and receptacles to a larger suite.



Kitchen millwork is another good example where doubling the size of the suite would not result in a doubling of the kitchen size and cost. The ‘base unit cost’ of supplying and installing the kitchen will remain constant with a moderate increase for scaling additional cabinets, countertops and tiling for the larger suite space.

Base Unit Cost Analysis

The example below shows the influence of applying base unit cost rationale when increasing unit area.

Influence of Base Unit Cost Example (costs are exampled only)

Base Unit Cost Components	Studio 350 sq.ft GFA (Costs)	1 Bed Unit 650 sq.ft GFA (Costs)	Comments
Site Servicing	$ 7,000	$ 7,000	Constant cost and no increase due to unit size
Plumbing Distribution	$ 4,000	$ 4,000	Constant cost and no increase due to unit size
Electrical Distribution	$ 3,000	$ 3,900	Assumes 30% increase above base costs due to larger floor area
Bathroom Fixtures	$ 3,000	$ 3,000	Constant cost and no increase due to unit size
Kitchen	$ 2,500	$ 3,250	Assumes 30% increase above base costs due to larger floor area
Fire Alarm System	$3,000	$3,000	Constant cost and no increase due to unit size
Sprinkler System	$2,000	$2,600	Assumes 30% increase above base costs due to larger floor area
Glazing Systems	$8,000	$8,000	Increasing unit size reduces 'constant' cost items by 42%
Entrance Door	$1,500	$1,500	Constant cost and no increase due to unit size
Totals	$34,000	$ 36,250	
Sq.ft Cost	$ 97.14	$55.77	
Cost Difference	$41.37		Increasing the unit area results in a $41.37 reduction of sq.ft cost
% Difference	42.6% or 57.4% reduction		Increasing the unit area results in a 42.6% or 57.4% reduction of sq.ft cost

Methodology Item 3 - Micro-Suite Cost Efficiencies (when reported on a cost per unit measurement)

Taking an aggregate of costs from the Altus Cost Guide for timber-framed construction for townhouses and assuming costs are based off a larger unit of 685 sq.ft the following unit costs have been developed:

Suite Type	GFA	Cost sq.ft	Cost Per Unit	Cost Diff	% Diff
1 Bed Apt	685	$173	$118,505		
Micro-suite	365	$218	$79,570	$38,505 (lower cost)	32 % lower cost

The calculations above indicate that unit costs for micro-suites compared to typical market units with a similar level of functionality are potentially lower by 32%.

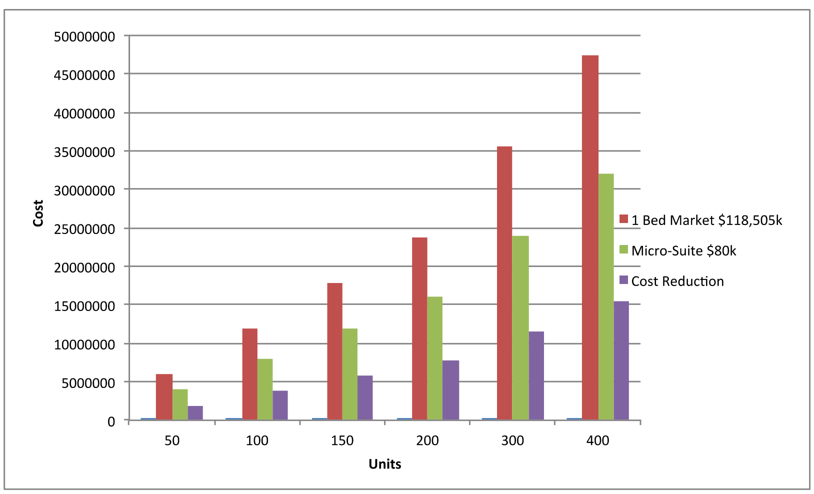
Lower Cost Micro-Suites - Up Scaling Developments

A 32% reduction in construction costs compounded over a larger-scale development or housing program can have a significant impact, such as reducing overall development costs to make a project financially viable or increasing the number of units for a given fixed capital budget. Building micro-suites should also reduce the amount of land required to build and hence overall development costs.

The following examples below show the potential cost savings or increases in the provision of housing units using containerized micro-suite type construction.

Cost Savings Comparison

Development Scale (units)	1 Bed Market $118,505k	Micro-Suite $80k	Cost Reduction
50	$5,925,250	$4,000,000	$1,925,250
100	$11,850,500	$8,000,000	$3,850,500
150	$17,775,750	$12,000,000	$5,775,750
200	$23,701,000	$16,000,000	$7,701,000
300	$35,551,500	$24,000,000	$11,551,500
400	$47,402,000	$32,000,000	$15,402,000



Unit Number Comparison

Capital Budget	1 Bed Market $113k	Micro-Suite $80k	Unit Increase	Unit No % Increase
$5,650,000	50	71	24	48%
$11,300,000	100	141	48	48%
$16,950,000	150	212	72	48%
$22,600,000	200	283	96	48%
$33,900,000	300	424	144	48%
$45,200,000	400	565	193	48%

Methodology Item 4 – Modeling using 'base unit costs' for Oneesan

In order to conduct cost modeling to evaluate the viability of utilizing containerized construction for larger scale housing developments a 'base unit cost' for Oneesan needs to be established. Calculating base unit cost and then deleting it from the reported total sq.ft of $218 leaves the 'quantitative unit costs'.

Quantitative unit costs related to building components and general provisions that are affected by the quantity and project schedule. Quantitative unit costs for example cover items such as super structure, insulation, exterior envelope, paint, drywall, flooring and site work and provisions for excavation, foundations, paving, fencing, scaffolding, etc. Costs for these items increase as a result of constructing suites with larger floor area.

Oneesan Sq.ft Cost	Base Unit Cost	Quantitative Unit Cost
$219	$109	$119

Base-unit cost for Oneesan were calculated using expensed costs shown in the project schedule of values. (See Appendix B – Oneesan Schedule of Values)

Cost Model 1 – 685 GFA 1 Bedroom Suite

Using the Oneesan project as a base unit type and applying the quantitative unit costs to only the additional unit area of 320 GFA the costs for a 685 GFA 1 bedroom market suite can be cost modeled as detailed below:

Oneesan Base Unit Type

Unit Type	GFA	Sq.ft Cost	Unit Cost
Oneesan Unit (base)	365	$219.00	$79,000

Cost Model 1 – Calculation

Unit Type	GFA	Sq.ft Cost	Unit Cost
1 Bedroom Unit	685	$219.00 (365 sq.ft)	$79,000
		$109.00 (320 sq.ft)	$34,880
Total 1 Bed Unit Cost			$113,880
Adjusted Sq.ft Cost		$166 .24	

Using the above logic and making appropriate adjustments, further modeling can be conducted

Cost Model 2 – 1005 GFA 2 or 3 Bed, 2 Bath Market Unit

Unit Type	GFA	Sq.ft Cost	Unit Cost
2 / 3 Bedroom, 2 Bath Unit	1005	$219.00 (365 sq.ft)	$79,000
		$109.00 (320 sq.ft)	$34,880
		$109.00 (320 sq.ft)	$34,880
Add 1 Bathroom ($8,000)		$ 8.00	$8,000
Total 2 Bed, 2 Bath Unit Cost			$156,760
Adjusted Sq.ft Cost		$156.00	

Methodology Item 5 – Comparative cost evaluation against conventional construction forms

Using the 2014 Construction Cost Guide published by the Altus Group – (see appendix A – Altus Cost Guide) the following baseline cost data has been calculated. Assumptions have been made to select appropriate costs and forms of development from the Altus guide that best represents the potential use of containerized construction.

			Average Reported Cost (Baseline Cost Data)
Residential Apartments	Concrete	Medium	$223.00
Townhouse (Walk-up)	Timber-frame	Medium	$163.00

Using the data developed in both Methodology Item 2 – Baseline Cost Data and Methodology Item 5 – Modeling using 'base unit costs' for Oneesan, a comparative evaluation for containerized construction can be made against conventional construction forms.

Methodology Item 6 - Comparative Cost Evaluation

Development Type	Construction Form	Type / Quality	Average Reported Cost
Containerized Construction	Containers	Medium	$166.00
Townhouse (Walk-up)	Timber-frame	Medium	$163.00
Residential Apartments	Concrete	Medium	$223.00

The results above suggest that the cost of containerized construction is comparable to wood- frame and more cost efficient than concrete type construction. Assuming efficiencies will be realized as containerized type construction develops and expertise is gained further costs reductions can be expected.

We can also compare wood-frame type construction costs by reversing the cost modeling analysis to reduce a market 685 suites at the previously calculated aggregate $170.00 sq.ft to a smaller 365 sq.ft micro-suite.

In order to do this analysis the base unit costs for both unit sizes would need to be assumed to be the same and the quantitative unit cost for the larger unit would need to be calculated.

Increase of sq.ft cost when reducing the area of a 685 GFA unit to 365

	Costs	Cost Sq.ft	Calculations
685 Unit cost	$116,450	$170	($170 X 685)
Base Unit Cost	$39,785	$109	($109 X 365)
Quantitative unit cost	$76,665	$112	($116,450-$39,785) / 685

Reversed Unit Cost	GFA	Cost Sq.ft	Cost
Base Unit Cost	365	$109	$39,785
Quantitative unit cost	365	$112	$35,840
Total Unit Cost			$75,625
Adjusted Sq.ft Unit Cost		$207	

Appendix A – Altus 2014 Cost Guide

Appendix B - Oneesan Project Schedule of Values

Appendix C - Post Occupancy Livability Survey