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International Growth Centre

Multi-storey versus single-storey residential construction cost analysis

Brian Halusan

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Multi-story Versus Single-Story Residential Construction Cost Analysis

By Brian Halusan, for the International Growth Centre
February 2017

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Introduction

The *Cost Model for Evaluating Low Income Housing Option* is designed to assist the Rwanda Housing Authority (RHA), City of Kigali (COK), Ministry of Infrastructure (MININFRA), or other agency to explore alternatives of an incremental housing strategy. This is an addendum to the original paper titled Building Affordable Neighborhoods in Kigali - A Framework for Incremental Development and Low Income House Building (Jitendra N. Bajpai, 2015). The original paper did not include a multi-story superstructure in the incremental housing cost analysis. The *Cost Model for Evaluating Low Income Housing Options* consists of three sub-modules (Infrastructure and Plot Services Sub-model, Dwelling Unit Sub-model, and Land Use, Housing Typology, Affordability and Cost Recovery Sub-model) and each has been updated to include up to a 3-story single-family residential superstructure. A 3-story superstructure will not require additional structural engineering or support; therefore, this low cost multi-story housing solution is a feasible option that provides a relative comparison to a single-story house.

The Cost Model projects an estimated total development cost based on the user's specific inputs into the model. The user can compare various superstructures, incremental configurations and quality of construction materials.

Parameters for the Hypothetical Case Study

The objective of this addendum is to evaluate and compare a single-story housing solution to a multi-story house. The Rwandan Ministries are searching for affordable housing solutions that will meet the housing needs of their population in the lower income quintiles while also preserving their limited land resource. A hypothetical case study has been created to compare the total development cost of a single-story and a two-story house. The following assumptions have been used in the model and these will be referenced throughout the addendum.

- The plot size is 36 square meters for the single-story house and 18 square meters for the two-story house.
- Land price equals $7.00 per square meter
- The foundation for the single-story house is 36 square meters and 18 square meters for the two-story house.
- The floor plans for the single- and multi-story houses both equal 36 square meters.
- Bathroom equals 6 square meters
- One room equals 15 square meters
- Two rooms equal 24 square meters (one 15 square meter room and one 9 square meter room)
- Wall height equals 3 meters
- Construction Materials
    - Walls are constructed with cement block and covered with cement plaster on both the interior and exterior sides of the walls

  - The roof system is composed of a milled eucalyptus frame, “local” clay tile covering, and PVC gutters
  - One steel door and one steel window per room
  - Plumbed with hot and cold water
  - The Above Average house has a limestone floor and the Multi-story floor is reinforced concrete, which is approximately 3 times more expensive than the limestone floor
- Hard cost contingency equals 10.0% of total hard construction cost
- General conditions equal 5.0% of total hard construction cost
- Overhead and profit equals 10.0% of total hard construction cost
- RWF/USD exchange rate is 750
- The on-site infrastructure will include a 500 meter trunk sewage line, 3,500 meters of tertiary roads (6 meters wide) with drainage, and 210 electrical connection points that are within 35 meters of each plot
- Density is 5 persons per plot
- Mortgage financing terms:
  - 10% down payment
  - 18% interest rate
  - 20-year loan term
  - Mortgagor debt service payment limited to 30% of income

Module One – Infrastructure and plot Services

The first module consists of the infrastructure services, which has been segregated into three components: Off-site Infrastructure, On-site Infrastructure, and On-plot Services. The infrastructure services in this model are based on utilities provided by Rwanda's Energy, Water and Sanitation Authorities (REG, and WASAC) and does not consider other renewable energy or zero waste management strategies. The Republic of Rwanda Ministry of Infrastructure ("MININFRA") is responsible for the planning and implementation of the infrastructure services to the development site. In May 2013, MININFRA provided the estimated installed costs (material and labor) on a per meter basis for each service, inclusive of a ten percent (10%) administrative fee (see Table 1).

Table 1: Off-site Infrastructure Cost

Administrative Cost	10%
RWF/USD	750

OFF-SITE INFRASTRUCTURE	Metric	RWF	Quantity	Total RWF	Total USD	USD/SqM
Electrical/Shallow Utilities	cost/m	21,750	500 m	1,962,500	15,950	0.16
Landscaping	cost/m^2	3,200	500 sqm	1,760,000	2,347	0.02
Roads						
Primary road	cost/m	650,000	500 m	357,500,000	476,667	4.77
Secondary	cost/m	400,000				
Storm Water Drainage	cost/m	175,000	500 m	96,250,000	128,333	1.28
Sanitary System (Treatment Plant)	cost/household	1,000,000				
Water System (Trunk Line)	cost/m	18,125	500 m	9,968,750	13,292	0.13
Total Off-Site Infrastructure				**477,441,250**	**636,588**	**8.72**

The Off-site Infrastructure includes the extension of electricity and shallow utilities, primary and secondary roads, urban public realm improvements, water, wastewater, and storm water drainage systems to the project site boundary. MININFRA would be responsible for the installation of these service and the costs would be recaptured through user fees. The Off-site Infrastructure costs are included in the estimated total development cost to provide a holistic project cost.

The On-site Infrastructure includes the extension of electricity and shallow utilities, tertiary roads, urban public realm improvements, water, wastewater, and storm water drainage systems from the project site to each individual site boundary (Table 2). The developer would be responsible for the installation of these services and the costs would be recapture as an allocable portion upon the sale of each individual site.

Table 2: On-site Infrastructure Cost

Administrative Cost	10%
RWF/USD	750

ON-SITE INFRASTRUCTURE	Metric	RWF	Quantity	Total RWF	Total USD	USD/SqM
Electrical	cost/m	21,750	35 m	837,375	1,117	0.01
Grading/Earthworks	cost/m ^{2}	300	100,000 sqm	33,000,000	44,000	0.44
Landscaping	cost/m ^{2}	3,200		-	-	-
Paths/Trails	cost/m	5,000		-	-	-
Roads (Tertiary)	cost/m	100,000	3,500 m	385,000,000	513,333	5.13
Storm Water Drainage	cost/m	25,000	3,500 m	96,250,000	128,333	1.28
Water System						-
Trunk line to Plot	cost/m	18,125	500 m	9,968,750	13,292	0.13
Water Tank	cost/household	350,000	100 HH	38,500,000	51,333	0.51
Total On-Site Infrastructure				**563,556,125**	**751,408**	**10.29**

The On-plot Services include the plot pre-development preparation, electrical, water, and sanitation connections, and storm water drainage systems. The developer would pay for the implementation of the services if they are provided as part of the project, or the future property owner will be responsible for the costs if the services are added later. The below input table contains the estimated costs per household for each of the services (Table 3). These costs are identical for each quality of construction category. These on-plot costs will be aggregated and included in the total development cost.

Table 3: On-plot Services Cost

QUALITY OF CONSTRUCTION		MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
ON-PLOT SERVICES							
Grading & Site Prep	cost/m ^{2}	500	500	500	500	500	500
Electricity							
Electrical Cable	cost/HH	227,500	227,500	227,500	227,500	227,500	227,500
Connection Fee	cost/HH	56,000	56,000	56,000	56,000	56,000	56,000
Potable Water/Drainage							
Plumbing Line	cost/HH	66,950	66,950	66,950	66,950	66,950	66,950
Connection Fee	cost/HH	11,000	11,000	11,000	11,000	11,000	11,000
Drainage	cost/HH	49,140	49,140	49,140	49,140	49,140	49,140
Storm Water Drainage	cost/HH	42,000	42,000	42,000	42,000	42,000	42,000
Sanitary System	cost/HH	135,000	135,000	135,000	135,000	135,000	135,000
Community Core Option	cost/HH	123,500	123,500	123,500	123,500	123,500	123,500

The estimated infrastructure costs provided by MININFRA do not include ongoing maintenance expenses or capital improvements. The Rwandan government is responsible for infrastructure maintenance, which would be funded with grants or loans provided by the African Development Bank Group (Republic of Rwanda Ministry of Infrastructure, n.d.).

The Infrastructure and Plot Services Sub-model outputs are inputs into the third module, Land Use, Housing Typology, Affordability and Cost Recovery Sub-model. The hypothetical case study is not based on an actual project site. The off-site and on-site infrastructure meters assumed in the model were randomly selected; however, the distances are consistent for all the incremental configurations so the outputs may be compared and analyzed. The on-plot services are based on actual historical implementation costs for similarly sized plots.

Module Two – Dwelling Unit

The second module, Dwelling Unit Sub-model, aggregates cost data by major house system to derive an estimated total hard construction cost for each of the incremental house configurations based on the "quality of construction" category. The first step in calculating the estimated construction cost is to define the "quality of construction" categories. The "quality of construction" categories include Minimal, Low, Average, Above Average, High and Multi-story. The classification grid is included in the *Cost Model for Evaluating Low Income Housing Options* (see the Annex), which provides a general overview of each house and specifies the construction materials and finishes used in each element of the house.

As a rule, the quality of construction materials and finishes used in each house system improves as the "quality of construction" category escalates. Moreover, the construction materials are coordinated to provide the most durable structure within each quality category. For example, a cement wall plaster is required for proper adhesion to a shell constructed with stabilized compressed earth block (SCEB), which contains between 5% and 10% cement. Since both materials contain a similar cement content, they will bond together better than a cement stabilized earth block and earth plaster. An earth plaster would be an inappropriate choice for a wall plaster because the earth plaster is a "softer" material and it will not properly adhere to the SCEB shell. The earth plaster will eventually separate from shell and expose the block to the harmful environmental elements. While using an earth plaster with SCEBs would lower the initial construction cost, the longer-term maintenance costs will be more expensive.

Most of the construction materials selected for this incremental housing project are locally manufactured, fabricated, or harvested. The locally sourced construction materials cost less, requires less transportation, improves the local construction industry through the creation of employment and skill development, and expands access to housing (MININFRA, n.d.). The pallet of materials and labor selected to build various incremental housing units reflect the stated strategies outlined in the National Housing Policy.

Once the pallet of materials and labor has been defined, the actual costs for each house system must be obtained through market research. This construction cost data is then inputted into a manipulative cost matrix (Table 4), categorized by major house system and by the "quality of construction." For the most accurate comparison, the construction cost should be updated to reflect the local construction industry and economic conditions. For the hypothetical case study, the estimated construction material cost for the on-plot services, foundation, shell, roof, floor, and finishes are based on construction material price data obtained in the city of Kigali markets. The labor estimates are based the daily rates charged by tradespeople and the duration to complete each task is based on actual construction experience in Rwinkwavu, Rwanda.

Table 4: Unit Cost of Dwelling Elements

QUALITY OF CONSTRUCTION		MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
FOUNDATION SYSTEM		**Granite w/ Earth Mortar**	**Granite w/ Earth Mortar**	**Granite w/ Cement Mortar**	**Granite w/ Cement Mortar**	**Granite w/ Cement Mortar**	**Reinforced Concrete**
	Cost/m^2	2,551	2,551	7,392	7,392	7,392	53,428
SHELL SYSTEM		**Mud Brick**	**CEB**	**SCEB**	**Cement Block**	**Fired Clay**	**Reinforced Concrete**
Wall Material	Cost/m^2	3,340	4,416	11,711	14,021	14,667	511,481
Electrical	Cost/m^2	2,000	3,000	4,000	5,000	6,000	5,000
Fenestration	Cost/Room	55,900	55,900	87,100	87,100	87,100	87,100
ROOF SYSTEM		**Eucalyptus-tree-Steel**	**Eucalyptus Milled - Steel**	**Steel - Steel**	**Eucalyptus Milled - Clay**	**Steel - Mfg Clay Tile**	**Eucalyptus Milled - Clay**
Framing/Covering	Cost/m^2	5,363	6,326	7,465	9,867	13,393	9,867
Roof Drainage	Cost/m^2			3,715	3,715	5,300	3,715
FLOOR SYSTEM		**Earthen**	**Cement Screed**	**Cement Screed**	**Limestone**	**Ceramic Tile**	**Concrete Slab**
	Cost/m^2	3,250	8,725	8,725	11,950	16,375	36,594
FINISHINGS							
Kitchen	Cost/HH		82,000	160,000	160,000	282,000	160,000
Bathroom	Cost/HH	222,325	222,325	322,325	380,325	380,325	380,325

The above cost metrics are used to calculate an estimated construction cost for each house element based on the selected size of the house (see Table 5 for example).

Table 5: Cost of Housing Components by Quality of Construction Category in RWF

	Sq Meters	Wall Height		
Finished House Size	36.0		Contingency	10.0%
Bathroom	6.0	3 m	General Conditions	5.0%
One Room	15.0	3 m	OH & Profit	10.0%
Two Room	24.0	3 m	RWF/USD	750

Construction Cost (RWF)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
On-PLOT SERVICES						
Grading & Site Prep	18,000	18,000	18,000	18,000	18,000	18,000
Electricity	283,500	283,500	283,500	283,500	283,500	283,500
Potable Water/Drainage	127,090	127,090	127,090	127,090	127,090	127,090
Storm Water Drainage	42,000	42,000	42,000	42,000	42,000	42,000
Sanitary System	135,000	135,000	135,000	135,000	135,000	135,000
Community Core Option	123,500	123,500	123,500	123,500	123,500	123,500
FOUNDATION SYSTEM	91,822	91,822	266,126	266,126	266,126	1,882,288
SHELL SYSTEM						
Bathroom	128,020	153,388	321,898	369,478	387,106	369,478
One Room	236,200	299,620	674,095	793,045	837,115	793,045
Two Room	400,280	501,752	1,113,392	1,303,712	1,374,224	1,303,712
ROOF SYSTEM						
Bathroom	38,610	45,546	80,493	97,790	134,587	
One Room	96,525	113,864	201,233	244,476	336,467	
Two Room	154,440	182,183	321,972	391,162	538,347	293,371
FLOOR SYSTEM						
Bathroom	19,500	52,350	52,350	71,700	98,250	
One Room	48,750	130,875	130,875	179,250	245,625	
Two Room	78,000	209,400	209,400	286,800	393,000	
FINISHINGS						
Kitchen		82,000	160,000	160,000	282,000	160,000
Bathroom	222,325	222,325	322,325	380,325	380,325	380,325

This data is then used to estimate the total construction cost of each of the incremental configurations. Following is a description of the five incremental configurations:

1) A plot with fully built foundation up to the plinth and access to a community toilet and stand pipe facility serving a 20-dwelling unit cluster (F, Comm.)
2) A plot with fully built foundation up to the plinth, a room, and access to a community facility of toilets and stand pipes for water (F, 1 Room, Comm.)
3) A plot with fully built foundation up to the plinth and a core of toilet, sink, and bath tray (F, Bath)
4) A plot with fully completed foundation up to the plinth, a core facility of toilet, sink and bath tray, and a room (F, Bath, 1 Room)
5) A plot with fully completed foundation up to the plinth, a core facility of toilet, sink, and bath tray, and two rooms (F, Bath, 2 Rooms)

The output of the Dwelling Unit Sub-model is an On-plot Services (Table 6), Superstructure Cost (Table 7), and an aggregated total hard construction cost (Table 8) for each of the five incremental housing configurations for both the single-story and multi-story superstructures. The single-story incremental configurations are categorized by the "quality of construction", providing a total twenty-five single-story variations. The multi-story category uses the same construction materials as the Above Average category. These construction materials used in the Above Average category are compatible with the Multi-story reinforced concrete superstructure. The Multi-story category provides a total of five configurations.

Table 6: On-plot Services Cost by Quality of Construction Category (RWF)

ON-PLOT SERVICES COST (RWF)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
Core Configurations	531,250	531,250	531,250	531,250	531,250	700,000
Non-core Configurations	756,988	756,988	756,988	756,988	756,988	756,988

Note: The On-plot Services costs, which are identical for each of the Core Configurations except for the multi-story house. The Multi-story configuration also includes the sanitary system cost of 135,000 RWF because retro fitting a sanitary system into a multi-story house is more difficult.

Table 7: Superstructure Cost by Quality of Construction Category (RWF)

SUPERSTRUCTURE COST (RWF)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	114,777	114,777	332,658	332,658	332,658	2,352,860
F, Comm Core, 1 Rm	591,621	795,226	1,590,412	1,853,622	2,106,667	3,344,166
F, Bath	625,346	809,288	1,503,991	1,681,775	1,935,493	3,490,114
F, Bath, 1 Rm	1,102,190	1,489,737	2,761,744	3,202,739	3,709,501	4,481,420
F, Bath, 2 Rm	1,416,246	1,925,957	3,559,946	4,158,867	4,817,456	5,486,468

Table 8: Total Construction Cost by Quality of Construction Category (RWF)

TOTAL CONSTRUCTION COST (RWF)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	646,027	646,027	863,908	863,908	863,908	2,884,110
F, Comm Core, 1 Rm	1,122,871	1,326,476	2,121,662	2,384,872	2,637,917	3,875,416
F, Bath	1,382,333	1,566,275	2,260,978	2,438,762	2,692,480	4,247,101
F, Bath, 1 Rm	1,859,177	2,246,725	3,518,732	3,959,726	4,466,489	5,238,408
F, Bath, 2 Rm	2,173,233	2,682,944	4,316,934	4,915,854	5,574,444	6,243,455

As stated earlier, the hypothetical case study assumes the same thirty-six (36 SQM) finished square meters for each of the incremental house configurations and the exchange rate is 750 RWF/USD. The estimated construction cost is inclusive of contingency, general conditions, overhead and profit percentages. The per square meter costs will allow the user to compare incremental configurations of the identical size (Table 9).

Table 9: Total Construction Cost per SqM by Quality of Construction Category (USD)

TOTAL CONSTRUCTION COST / SQM (USD)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	24	24	32	32	32	113
F, Comm Core, 1 Rm	42	49	79	88	98	150
F, Bath	51	58	84	90	100	157
F, Bath, 1 Rm	69	83	130	147	165	194
F, Bath, 2 Rm	80	99	160	182	206	231

Module Three – Land Use, Housing Typology, Affordability, and Cost Recovery

The third module, Land Use, Housing Typology, Affordability and Cost Recovery integrates the outputs of the first two modules with the city specific norms of land use allocation, private lender financing terms, resident income requirements, plot size, and the incremental housing configuration to calculate a total development cost per housing unit (Table 10). A monthly debt service payment and percent of owner's income is calculated to ensure the targeted beneficiary's income level is sufficient to meet the financial obligations. Below is the model results based on the hypothetical case study.

Table 10: Land Use, Housing Typology, Affordability & Cost Recovery Model

LAND-USE, HOUSE TYPOLOGY, AFFORDABILITY, & COST RECOVERY

LAND-USE

	Land (SqM)	Land (%)	HMS Target (%)	Land Price (USD/SqM)
Total Developable Land	**100,000**	**100.0%**		
Commercial/Retail/Mixed-Use	10,000	10.0%	50.0%	7.00
Community Facilities	2,000	2.0%		7.00
Education	3,000	3.0%		7.00
Health	3,000	3.0%		7.00
Infrastructure/Circulation	25,000	25.0%	10.0%	7.00
Open Space	2,000	2.0%		7.00
Residential Category	**55,000**	**55.0%**	**40.0%**	**7.00**
Social	0	0.0%	15.0%	7.00
Affordable	55,000	100.0%	50.0%	7.00
Mid-Range	0	0.0%	30.0%	7.00
Premium	0	0.0%	5.0%	7.00

	Area (SqM)	USD	USD / SqM
MARKETABLE LAND	**73,000**	**511,000**	**7.00**
Residential Land	55,000	385,000	7.00
Commercial/Community Services Land	18,000	126,000	7.00
NON-MARKETABLE LAND	**27,000**	**189,000**	**2.59**
Infrastructure/Circulation	25,000	175,000	2.40
Open Space	2,000	14,000	0.19
TOTAL	**100,000**	**700,000**	**7.00**

DENSITY	
Persons/Plot	5
Population Density/ha	917

HOUSE TYPOLOGY & AFFORDABILITY

FINANCING		Down payment	Int Rate	Term (Yrs)	% of Mo Income		Other Cost				
Loan Terms		10.0%	18.0%	20	30.0%		25.0%				
Monthly Income (USD)		108	274	233	356	233	382	358	439	437	522
Maximum Purchase Price		2,330	5,921	5,034	7,683	5,029	8,244	7,733	9,491	9,433	11,278

HOUSE TYPOLOGY	Total	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Type H	Type I	Type K
Plot Length (m)		10.0	10.0	10.0	10.0	10.0	10.0	10.0	4.3	10.0	4.3
Plot Width (m)		3.6	3.6	3.6	3.6	3.6	3.6	3.6	4.2	3.6	4.2
Plot Area (SqM)	55,000	36.0	36.0	36.0	36.0	36.0	36.0	36.0	18.0	36.0	18.0
Land Purchase Price (USD)		7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Typology Distribution	100%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Number of Plots	1,833	152.8	152.8	152.8	152.8	152.8	152.8	152.8	305.6	152.8	305.6
Residential Category		Affordable	Affordable	Affordable	Affordable	Affordable	Affordable	Affordable	Affordable	Affordable	Affordable
Quality of Construction		Above Average	Multi-Story	Above Average	Multi-Story	Above Average	Multi-Story	Above Average	Multi-Story	Above Average	Multi-Story
Incremental House Configuration		F, Comm Core	F, Comm Core	F, Comm Core, 1 Rm	F, Comm Core, 1 Rm	F, Bath	F, Bath	F, Bath, 1 Rm	F, Bath, 1 Rm	F, Bath, 2 Rm	F, Bath, 2 Rm

DEVELOPMENT COST (USD)	Total	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Type H	Type I	Type K
Off-Site Infrastructure	479,621	314	314	314	314	314	314	314	157	314	157
On-Site Infrastructure	566,129	371	371	371	371	371	371	371	185	371	185
On-plot Services	1,735,332	708	933	708	933	1,009	1,009	1,009	1,009	1,009	1,009
Non-Marketable Land	142,397	93	93	93	93	93	93	93	47	93	47
Marketable Residential Land	385,000	252	252	252	252	252	252	252	126	252	126
Construction Cost	8,220,646	444	3,137	2,471	4,459	2,242	4,653	4,270	5,975	5,545	7,315
Soft Cost	2,740,215	148	1,046	824	1,486	747	1,551	1,423	1,992	1,848	2,438
Total Cost	14,269,342	2,329	6,146	5,033	7,908	5,029	8,244	7,733	9,491	9,433	11,278
Monthly Loan Payment (USD)		32.36	85.37	69.91	109.84	69.85	114.50	107.41	131.83	131.02	156.65
% of Income		30.0	31.1	30.0	30.9	30.0	30.0	30.0	30.0	30.0	30.0

DEVELOPMENT COST (% of Total)	Total	Type A	Type B	Type C	Type D	Type E	Type F	Type G	Type H	Type I	Type K
Infrastructure	19.5%	59.8%	26.3%	27.7%	20.5%	33.7%	20.5%	21.9%	14.2%	18.0%	12.0%
Non-Marketable Land	1.0%	4.0%	1.5%	1.9%	1.2%	1.9%	1.1%	1.2%	0.5%	1.0%	0.4%
Marketable Residential Land	2.7%	10.8%	4.1%	5.0%	3.2%	5.0%	3.1%	3.3%	1.3%	2.7%	1.1%
Construction Cost	57.6%	19.0%	51.0%	49.1%	56.4%	44.6%	56.4%	55.2%	63.0%	58.8%	64.9%
Soft Cost	19.2%	6.3%	17.0%	16.4%	18.8%	14.9%	18.8%	18.4%	21.0%	19.6%	21.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

COST RECOVERY

Cost To Be Recovered		Recovered Cost			
	USD	Commercial	Residential	Total	Surplus / (Deficit)
Marketable Land	700,000	172,603	527,397	700,000	-
Off-Site Infrastructure	636,588	156,967	479,621	636,588	-
On-Site Infrastructure	751,408	185,279	566,129	751,408	-
Non-Marketable Land	189,000	46,603	142,397	189,000	-
Total Cost To Be Recovered	2,276,997	561,451	1,715,545	2,276,997	-

The module's dynamic variables include land distribution, land price, density, financing terms, household monthly income, plot size, quality of construction, and incremental house configuration. The user can create a development site with up to ten different house typologies or evaluate a developer's proposal. Prior to evaluating the results of this module, an analysis of the aggregated construction cost will provide some insightful information.

Housing Analysis

An analysis of the aggregated construction cost will provide users with information that may assist with evaluating the incremental housing alternatives, leading to more informed decisions.

Hard Construction Cost Matrix

The hard construction cost, comprised of materials, labor, and general contractor's overhead and profit, traditionally represents between 60% and 80% of the total development cost. Construction soft costs, financing fees, carrying cost, and developer's overhead and profit account for the remaining 20% to 40% of the total development cost. Therefore, as the finished square meters of the incremental house increases, the total development cost will also increase. For this case study, the fully finished house is assumed to be thirty-six (36) square meters. The total construction cost of each incremental house configuration (Table 11) is divided by thirty-six (36) to produce the cost per square meter metric in Table 12.

Table 11: Total Construction Cost by Quality of Construction Category (USD)

TOTAL CONSTRUCTION COST (USD)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	861	861	1,152	1,152	1,152	4,070
F, Comm Core, 1 Rm	1,497	1,769	2,829	3,180	3,517	5,392
F, Bath	1,843	2,088	3,015	3,252	3,590	5,663
F, Bath, 1 Rm	2,479	2,996	4,692	5,280	5,955	6,985
F, Bath, 2 Rm	2,898	3,577	5,756	6,554	7,433	8,325

Table 12: Total Construction Cost per SqM by Quality of Construction Category (USD)

TOTAL CONSTRUCTION COST / SQM (USD)	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	24	24	32	32	32	113
F, Comm Core, 1 Rm	42	49	79	88	98	150
F, Bath	51	58	84	90	100	157
F, Bath, 1 Rm	69	83	130	147	165	194
F, Bath, 2 Rm	80	99	160	182	206	231

The Low category will be used to evaluate the per square meter cost changes across the configurations. The F, Comm Core configuration establishes the baseline for the most basic incremental house at a cost of $861 ($24 per SqM). The F, Comm Core, 1 Rm configuration adds approximately $910 ($61 per SqM), for a total construction cost of $1,769 ($49 per SqM). The fifteen (15) square meter room (inclusive of the shell, roof, and floor elements) is forty-two percent (42%) of the total finished square meters and the construction cost for this room is approximately $61 per square meter.

The F, Bath configuration, with a total cost of $2,088 ($58 per SqM), cannot be directly compared to the F, Comm Core and F, Comm Core, 1 Rm configurations because the former house configuration contains a private bathroom facility. The two previously discussed configurations utilize a community bathhouse that is shared among 20 households, resulting in a lower total construction cost. A community bathhouse is a more feasible solution to maximize the efficiency of financial resources and the number of beneficiaries, rather than provide a private restroom and douche for a similarly sized house.

The next incremental house configuration, F, Bath, 1Rm, adds a fifteen square meters (15 SqM) room at a cost of approximately $910 ($61 per SqM). The last incremental configuration, F, Bath, 2 Rm, adds a nine square meter (9 SqM) room at a cost of $581 ($65 per SqM) to the previous house configuration and cost.

Whether a house configuration has a community bathhouse or private bathroom facility, the "entry level" configurations (F, Comm Core and F, Bath) requires the highest investment on per square meter basis because the on-plot services and foundation for a thirty-six square meter (36 SqM) finished house is provided. Each additional room that is added to the "entry level" house configuration cost less on a per square meter basis.

Higher Quality of Construction Analysis

A second data analysis is the comparison of the incremental cost for a higher quality of construction (Table 13). Constructing houses with the lowest quality of materials will maximize the number of incremental housing units given a finite budget. It is also worth noting that it is possible to produce a high-quality house with less expensive construction materials if skilled construction laborers are contracted. This section will analyze the significance of the increase in construction cost using higher quality of construction materials. Beyond the cost impact, a higher quality house theoretically will have a longer useful life, will require less maintenance and will have a lower operating cost.

Table 13: Quality of Construction Percentage Change from 'Low', (Low=0%)

INCREMENTAL HOUSE CONFIGURATION	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	0.0%	0.0%	33.7%	33.7%	33.7%	372.6%
F, Comm Core, 1 Rm	-15.3%	0.0%	59.9%	79.8%	98.9%	204.9%
F, Bath	-11.7%	0.0%	44.4%	55.7%	71.9%	171.2%
F, Bath, 1 Rm	-17.2%	0.0%	56.6%	76.2%	98.8%	133.2%
F, Bath, 2 Rm	-19.0%	0.0%	60.9%	83.2%	107.8%	132.7%

The materials used in each of these configurations may be viewed in the DU Quality Indicators tab of the model or see the chart in Annex 1. The Low category establishes the baseline (0%) for this comparison. The Minimal category uses construction materials and technologies that do not meet Rwanda's buildings codes. Furthermore, the Minimal category's lifespan is shorter, the house will require constant maintenance, the structure is not as resilient to earthquakes and landslides, and the environment is more vulnerable to health hazards. For these reasons, the Minimal category is not recommended as an incremental housing solution.

The F, Bath, 1 Rm house configuration will be used to discuss the results presented in the above chart. The Minimal quality of construction is approximately 17% less expensive than the Low quality category. Most of the construction cost decrease is due to installing an adobe floor, which does not require cement. The labor cost to produce either the cement screed or adobe floor is nearly identical. The adobe floor cost approximately 268% less than the cement screed floor due to the quantity of cement required.

The significant cost increase arises as the quality of construction is upgraded from the Low to the Average category. The Average category includes a cement mortar foundation, stabilized compressed earth block (SCEB), and a steel roof frame. While constructing with these materials cost approximately 57% more, the life expectancy of this house is conservatively estimated to be three times longer than the Low house life expectancy (30 years versus 10 years). **The longer house life cycle exceeds the additional cost in construction materials** (3.0x versus 0.6x), which is a significant factor.

As the quality of construction is improved to the Above Average, the incremental increase in construction cost is less significant, approximately 20% (76.2% vs 56.6%). Cement block is used in the construction of this house and while the material is superior to SCEBs, the cost of the material is not significantly greater. The clay tile roof covering used in this category is not significantly more expensive than a steel roof covering; however, the thermodynamic and acoustic qualities are superior to the steel roof covering. **A clay tile roof maintains a more constant internal temperature, reduces sound reverberation, and may last 100 or more years compared to 25 years for a steel roof**.

The High category house is almost twice the cost of the Low category house and approximately 23% more expensive than the Above Average category. The increase in cost of this category is due mainly to the superior construction materials and finishings, which enhances the aesthetics of the house. For example, the shell is constructed with fired clay brick, the roof covered with manufactured clay roof tiles, the floor is finished with ceramic tile, and the house contains more internal and external lighting. While some of these construction materials may exceed affordable housing requirements, using locally manufactured fired clay brick will produce a house that will remain standing for many decades and support the local economy.

The Multi-story category is 133% and 57% more expensive than the Low and Above Average category, respectively. The Above Average category is used as the comparison category for the Multi-story house because each of the house elements is constructed using the same shell (concrete block) and roofing materials (milled eucalyptus frame and "local" clay tile), and finishings. Therefore, the major cost driver in the Multi-story category is that a two- or three-story structure necessitates reinforced concrete columns, beams and floor slab, which are assumed to be fully constructed during the initial phase. Furthermore, skilled construction labor and additional equipment are required for proper erection of this superstructure.

Another contributing factor to the higher construction cost, although less significant, is that the On-plot Services require more upfront investment. A private sanitary system is included in the F, Comm Core and F, Comm Core, 1 Rm configurations, in addition to the shared community bathhouse, because retrofitting the plumbing in a multi-story structure is more difficult and costly. Therefore, the plumbing is installed during construction of the superstructure. The house may be connected to the central sanitation system when it becomes available in the neighborhood. The plumbed sanitary system adds an additional cost of $180 (or $5 per square meter).

Construction Cost Increase as Incremental House Increases in Size

A second data analysis performed is the increase in construction cost as the incremental configuration increases in size. Each incremental configuration is compared to the F, Bath. The F, Comm Core and F, Comm Core, 1 Rm configurations use a community bathhouse, whereas the other three configurations have a private bathroom facility. Therefore, the table illustrates in the cost impact of providing a private bathroom facility.

Table 14: Percentage Construction Cost Increase as Incremental House Increases in Size

INCREMENTAL HOUSE CONFIGURATION	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	-53.3%	-58.8%	-61.8%	-64.6%	-67.9%	-28.1%
F, Comm Core, 1 Rm	-18.8%	-15.3%	-6.2%	-2.2%	-2.0%	-4.8%
F, Bath	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
F, Bath, 1 Rm	34.5%	43.4%	55.6%	62.4%	65.9%	23.3%
F, Bath, 2 Rm	57.2%	71.3%	90.9%	101.6%	107.0%	47.0%

This comparison highlights that a development which utilizes a community bathhouse is approximately 60% less expensive than constructing housing units with a private bathroom facility. Beneficiaries could add a private bathroom as financial resources allow; however, a community facility is more economical for the government to implement. The only other trend in Table 14 that requires highlighting is the low percentage increases in the Multi-story category. Since the superstructure is built in the F, Comm Core configuration, the only additional construction cost is related to the infill walls, roof, and finishings. As a result, the **incremental increases in the Multi-story category are small compared to the other categories**.

The results presented in this table do not reveal a trend that would significantly influence the user to select a specific incremental configuration.

Multi-Story Versus Single-Story Analysis

The multi-story house is the most expensive proposed incremental housing option as estimated with the construction materials currently available in the marketplace (Table 11). While many organizations are experimenting with other “low cost” or “green” construction materials and technologies, none of them have proven to be as affordable as those currently available in the marketplace.

Table 15 compares the Multi-story category construction to each of the other quality of construction categories. The construction cost for the single-story options are shown as a percentage decrease compared to the Multi-story option.

Table 15: Multi-Story Versus Single-Story Construction Cost Comparison

INCREMENTAL HOUSE CONFIGURATION	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
F, Comm Core	-78.8%	-78.8%	-71.7%	-71.7%	-71.7%	0.0%
F, Comm Core, 1 Rm	-72.2%	-67.2%	-47.5%	-41.0%	-34.8%	0.0%
F, Bath	-67.5%	-63.1%	-46.8%	-42.6%	-36.6%	0.0%
F, Bath, 1 Rm	-64.5%	-57.1%	-32.8%	-24.4%	-14.7%	0.0%
F, Bath, 2 Rm	-65.2%	-57.0%	-30.9%	-21.3%	-10.7%	0.0%

The Single-story F, Comm Core configuration's construction cost is between 72% and 79% less expensive than the Multi-story category because the entire superstructure is built in this phase. Since only the foundation and a community bathroom facility is being provided in the single-story options, the construction costs comparison is not relative. As the incremental house configurations increase in number of completed rooms, the construction cost comparison become more relative.

The conclusion that can be drawn from Table 15 is the total development cost of the multi-story house will be more expensive than the single-story house due to the available construction materials to build a vertical structure. Until a more cost effective construction material becomes available, a multi-story superstructure will remain the most expensive incremental housing option. However, the Multi-story category housing option should not be dismissed solely based on the construction cost. **Weighing the higher construction cost against other criteria** such as the annual maintenance cost, land cost, the superstructure's life-cycle, and ability to withstand daily (heat, rain, insects, etc.) and extreme (earth quakes, flood, landslides, etc.) environmental factors, will lead to selecting the optimum solution. This will be further explored in the Incremental Housing Strategy Considerations Section.

Above Average Single-Story and Multi-Story Configuration Comparison

This costing model was created with dynamic variables for the user to design a project that meets the government's development criteria, objectives, and available financial resources. The total development cost will follow similar trends discussed in the previous sections since the construction costs typically represent between 60% and 80% of the total development cost. To accurately compare a single- and multi-story incremental house configuration, a house with the same finished square meters and quality of construction has been selected. Refer to the Hypothetical Case Study section for a complete listing of the assumptions.

Since the assumptions are similar for both the Above Average and Multi-story configurations, the total development cost and required monthly income provide an appropriate comparable analysis. Table 16 contains the total development cost and required income for all five incremental configurations. (See Table 10 for complete details.)

Table 16: Above Average Single-Story and Multi-Story Configuration Comparison (USD)

	TOTAL DEVELOPMENT COST COMPARISON (USD)			MONTHLY INCOME REQUIRED (USD)		
INCREMENTAL CONFIGURATION	**ABOVE AVERAGE**	**MULTI-STORY**	**MULTI-STORY TDC % INCR**	**ABOVE AVERAGE**	**MULTI-STORY**	**MULTI-STORY TDC % INCR**
F, Comm Core	2,329	6,146	163.8%	108	274	154.2%
F, Comm Core, 1 Rm	5,033	7,908	57.1%	233	356	52.6%
F, Bath	5,029	8,244	63.9%	233	382	63.9%
F, Bath, 1 Rm	7,733	9,491	22.7%	358	439	22.7%
F, Bath, 2 Rm	9,433	11,278	19.6%	437	522	19.6%

The total development cost displayed in Table 16, confirms that the multi-story configurations require more initial investment than a single-story incremental structure. For example, the most basic configuration, F, Comm Core for the multi-story option, cost slightly more than two times the single level configuration. The cost variance between these two configurations exists because the reinforced concrete footings, columns, beams, and slabs are constructed in the initial phase to maximize construction efficiency and to produce a fully integrated superstructure. However, as the incremental configurations increase in size, the total development cost gap between the Above Average and Multi-story house decreases to 20.2%.

The Table also summarizes the monthly income required based on the financing terms stated in the Hypothetical Case Study section. The income required calculation assumes the beneficiary would finance the total project cost and no government agency or other nongovernmental organization would provide a revenue subsidy. If the government provided either a construction or a revenue subsidy, the monthly income requirement would decrease and may benefit families in the lower income tiers. The development cost per housing unit will be a major factor in determining an incremental housing strategy; however, there are many other factors that are worth considering. The following section will discuss some factors that may be considered prior to making a final incremental housing strategy decision.

Incremental Housing Strategy Considerations

The total construction cost to build a housing unit is a significant factor in choosing an incremental housing strategy; however, this is only one of many other factors that require consideration prior to selecting an appropriate incremental housing solution. One potential tool that may be used to assist with evaluating relevant selection criteria is a decision matrix (Table 17). The decision matrix also provides the user and the public with a transparent system that identifies, scores, and ranks the housing options, which also assists to minimize subjective bias in the selection process. Following is a hypothetical decision matrix for the case study.

Table 17: Decision Matrix

		QUALITY OF CONSTRUCTION SCORE					
CRITERIA	**WEIGHT**	**MINIMAL**	**LOW**	**AVERAGE**	**ABOVE AVERAGE**	**HIGH**	**MULTI-STORY**
Low Total Development Cost	10	6	5	4	3	2	1
Maximal House Lifecycle	9	1	2	3	5	4	6
Minimal House Footprint	8	1	1	1	1	1	6
Self-build Option	5	6	6	3	3	3	2
Local Material & Labor Sources	5	2	2	5	5	4	3
Operationalize Construction Process	4	6	6	4	3	2	1
Low Maintenance Cost	1	1	2	3	4	5	6
Total Score		142	142	134	139	112	147

The first step is for the user to identify the criteria that will be used to evaluate an incremental housing project. Each criterion will include text defining the metric and how it will be measured. Each chosen criterion is assigned a weight between zero and ten, ten being the most important criterion. Each of the Quality of Construction categories are assigned a score between zero and six, six being the highest score. The score assigned to each criterion by quality of construction category is based on the categories ability to meet the defined criterion. The higher the score, the better the category satisfies the criterion.

The criterion weight and score are multiplied together and the individual criterion scores are summed to calculate a total score. The quality of construction category with the highest score is the housing solution that best satisfies the project's goals and objectives. The following sections will discuss the importance of evaluating other selection criteria in addition to the construction cost.

Low Total Development Cost per Housing Unit

Government agencies that develop and administer affordable housing programs have a primary goal of balancing the amount of subsidy funds provided to a project and the number of beneficiaries impacted by the project. Maximizing of the number of individual and family beneficiaries creates great statistical metrics for the government or donor organizations;

however, the long-term consequences of those decisions could lead to unforeseen and undesirable results.

For example, if a government agency provides subsidy funds to construct an F, Comm Core configuration because this configuration has the lowest total development cost per housing unit, this strategy will maximize the number beneficiaries in the lowest income quintile. However, if the beneficiaries are unable to improve the structure for many years, if ever, the house foundation may begin to deteriorate from exposure to the destructive environmental elements. The house foundation needs to be in good condition prior to further construction; otherwise, the risk of future structural failure increases. Either a government agency, non-governmental organization, or the property owner will need to provide additional construction capital to restore the foundation. Using additional government resource or grants to repair a house foundation is not an efficient use of limited financial resources.

Furthermore, if many low-income beneficiary's house foundations suffer a similar condition, this community is at a higher risk of transforming into a blighted neighborhood. In the short-term, maximizing the number of beneficiaries produces great public relations; however, if the subsidy is not sufficient to produce a quality foundation for the beneficiaries to build upon, the assistance may create longer-term problems.

Maximal House Lifecycle

A building's lifecycle may be increased by using higher quality construction materials. An incremental housing development may be in transition for 20 years before the beneficiaries can fully complete construction of their house (Jitendra N. Bajpai, 2015). If the construction materials used in the foundation have an estimated lifecycle of 30 years, the entire community may require substantial capital to rehabilitate the foundations and other house components within a few years after the anticipated fully developed community.

A reinforced concrete superstructure built per the international building code has several advantages compared to superstructures built with other, less expensive construction materials. First, a reinforced concrete superstructure should last a minimum of one hundred (100) years, it is safer, and performs better in seismic zones. The multi-story superstructure is designed to withstand earthquake tremors and the infill walls are devised to collapse (in higher magnitude earthquakes). Infill walls that collapse will protect the superstructure from destruction, safeguard the occupants of the house, and reduce the repair cost following a natural disaster. Infill walls are easier and less expensive to replace than an entire superstructure.

Minimal House Footprint

Developable land in Rwanda is a scarce resource and a goal of the City of Kigali is to implement better land management practices through the preservation of wetlands, open spaces, community facilities, and city wide infrastructure (Planet Consortium, 2012). Evaluating a development project's total land consumption becomes an important selection criterion since almost three hundred and fifty thousand (350,000) homes need to be built in the City of Kigali (Planet Consortium, 2012). An advantage of the Multi-story configuration in the hypothetical case study is that the house requires only half the foundation footprint as that of the single level house. The multi-story configuration allows for greater density and contributes to better land management practices. Another advantage of the smaller multi-story footprint is the lower land cost.

The land price used in the hypothetical case study is $7 per square meter. The land cost represents approximately 1.0% of the total development cost for F, Bath, 2 Rm multi-story configuration and about 11.0% for the single-story F, Comm Core configuration. If land in a more central area in Kigali was secured for an incremental housing development project at cost of $50 per square meter, then the land would represent between 7.5% and 46.4% for the same configurations. Land as percent of cost in the hypothetical case study is not a significant contributor to the development budget; however, as the price of land increases, financing affordable housing projects will become more difficult and require more subsidy funds.

Self-build Option

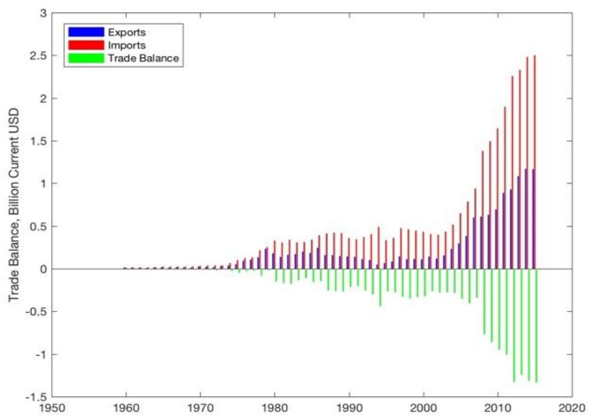
One of the basic premises in Building Affordable Neighborhoods in Kigali article is "to develop new clusters of mixed use and mixed income green communities that will promote incremental self-build housing strategy with the focus on meeting the needs of low income groups." (Jitendra N. Bajpai, 2015) Thus, the self-build criterion is heavily weighted in the decision matrix. The reinforced concrete multi-story superstructure scores very low because skilled labor is required to properly build the frame. However, 'self-build' can be conceived differently. Once the superstructure is finished by skilled labour, the property owners and community can 'self-build' the remainder of the house. It can indeed be prudent to construct the critical elements of the house (foundation, load bearing walls, plumbing, etc) with qualified contractors. This may lead to a different weighting.

Local Material and Labor Sources

Incremental housing projects that can utilize locally sourced materials and labor have the possibility of a lower production cost, require less government subsidy, and provide a boost to the local economy. Locally produced materials incur lower transportation cost, avoid import tariffs and taxes, and reduced lead times for product delivery. Another significant factor for utilizing local material and labor is derived from the impact of the construction industry on the balance of trade, and relatedly, the macroeconomic theory of the multiplier effect.

Rwanda is facing a severe trade deficit, with imports growing far more quickly than exports in the past decade (Figure 1). This must be addressed in order to uphold long-run macroeconomic stability and to service medium-run external obligations. Rwanda imported $82.76 million worth of cement in 2015, constituting 4.3% of Rwanda's total import bill, and equivalent to 6.7% of Rwanda's trade deficit and 12% of exports. Cement was consistently one of the top four most imported goods in Rwanda.[1] This illustrates how- with accelerated house construction- reducing Rwanda's reliance on imported materials can have a significant impact on the trade balance, and macroeconomic health in Rwanda. However, imported cement still tends to be higher quality, and no more expensive, and thus low-income residents may suffer from this attempt at local sourcing.

Figure 1. Rwanda's Trade Balance, 1960-2015 (English, 2016)



In addition, sourcing from the local economy, all else equal, has a significantly greater effect on income growth and poverty reduction, through the multiplier effect. If the City of Kigali spends one million dollars ($1,000,000) on an incremental housing development project, what is the final domestic income that results? This depends on how the direct beneficiaries spend the money they receive. If the beneficiaries are abroad, we can assume none of their earnings are spent in Rwanda. Domestic beneficiaries, by contrast, will spend most of their earnings in the local economy (the remainder being saved, or spent on imports). The share of income spent on the local economy is called the marginal propensity to consume (MPC). Those domestic businesses and people benefiting from their spending will also go on to spend a share in the local economy (in line with the MPC). And so on for recipients of that spending.

The final multiplier on the initial investment is calculated as:[2]

Multiplier = 1 / (1 - MPC) = 1 / (1 - 0.8) = 1 / 0.2 = 5

The Multiple Effect in theory says that the City of Kigali's $1,000,000 investment will produce $3,361,600[3] of economic activity in the domestic economy.

[1] http://statistics.gov.rw/statistical-publications/subject/quarterly-%26-annual--trade
[2] (Investopedia, LLC, n.d.)
[3] A + A*MCP + B*MCP + C*MCP + D*MCP, where MCP = 0.8, A = $1,000,000, B = A*MCP, C = B*MCP, D = C*MCP

However, if 50% of the City's spending goes to imported materials, this spending on the local economy is not only foregone directly, but we also lose its multiplier effect. Thus, the impact of the $1 million spending falls to *$500,000**3.361=$1,680,500.

Therefore, a small investment by the government, donor organization, or developer can have a much larger positive impact in the local economy, where it is spent on local content. The government and donor organizations could require that the investment be used to purchase only locally manufactured products if the meet building codes. As a result, incremental projects that utilize more locally produced materials and labor score higher in the decision matrix.

Operationalize Construction Process

The construction cost may be significantly reduced through optimization of the construction process. For example, producing a single house model across the entire development site is efficient because after the first house is built, the entire process is replicated to resemble an "assembly line" in a manufacturing plant. Assembly lines minimize waste and maximize labor productivity. Construction teams organized around the major house elements (foundation, shell, roof, utilities, floor, and finishes) can efficiently move from one house to the next and the labors can develop master-level skills. Additionally, the construction material procurement process is simplified as the purchase orders will be identical and a pre-determined delivery schedule may be implemented. 'Repeated' houses can also ease financing constraints, by making it easier for banks to assess the value of each building.

A central drawback to producing only one house model on a site is that families come in various sizes and the house is not designed to meet their specific housing needs. This may result in either an under or an over-sized house for a beneficiary resulting in an inefficient use of government financial resources.

A house that is too large for a target beneficiary results in government over-subsidization and potentially a mortgage payment the owner may not be able to financially afford.

At the other end of the spectrum, a beneficiary with a large household placed in house is too small results in an overcrowding situation. Inadequately sized water, waste, and electrical systems may result in system failures and potentially dangerous living conditions. Overcrowding may also lead to an increased risk of disease transmission and other health related issues, especially if the house is not properly ventilated or does not receive adequate light.

Another potentially hazardous situation may arise if the owner adds lean-to room(s) to the house to create additional space. A lean-to addition is a free-standing structure with a sloping roof and three walls that abuts the wall of another structure. If the lean-to foundation, shell, and roof are not properly integrated into the superstructure, the lean-to addition could collapse or cause damage to the house. Informal poor quality extensions can also destroy the neighborhood functionality and character.

To mitigate potential financial hardships, overcrowding and unsafe living conditions, a development site with assorted typologies designed to accommodate various household sizes may provide a more diverse community with respect to education, income, professions, and age. A good compromise, to optimize the benefits of uniformity while minimizing the downsides, is to develop a small number of clear housing typologies. A beneficiary who can select, from a Type A, B, or C house, the most appropriate design for their family, may experience a higher level of satisfaction and sense of ownership, while complications for design, laborers, and financiers, remain few. A diverse development site may lose some construction efficiencies; however, a portfolio with a limited number of typologies will remain very efficient.

Low Maintenance Cost

Buildings require continuous maintenance to reach their anticipated lifespan. Building maintenance is often overlooked by property owners; moreover, property owners do not reserve adequate financial resources for future repairs. A building superstructure that uses higher quality construction material will require a higher initial investment; however, the long-term financial burden to the property owner may be lower due to lower maintenance expenses.

An owner may be able to save more disposable income and secure sufficient financial resources to finish the construction of their incremental house if less resources are used for maintenance expenditures. Fewer housing units will be constructed with the same finite budget; however, lower long-term maintenance expenses have the possibility of producing more successful developments.

Results

Based on the defined criterion for the hypothetical case study, the multi-story option scored slightly higher than the minimal and low categories. The multi-story incremental housing solution would best meet the goals and objectives of the implementing organization, given the weighting applied. If different criterion were weighted differently or other selection criteria identified, a different result can emerge. The benefits of the decision matrix is that is minimizes subjectively and creates transparency.

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ANNEX 1: Quality of Construction Indicator

CATEGORY	MINIMAL	LOW	AVERAGE	ABOVE AVERAGE	HIGH	MULTI-STORY
GENERAL DESCRIPTION	A structure deficient in finishes typical for its use, or below standard building codes. Usually built as a shell or outside cities or before standard building codes were established.	The same as "Average", but with no extras. Built at the lowest practical cost to still pass building codes. Very plain but substantial buildings. Typically speculative construction or from stock plans and off-the-shelf components. May be considered standard in low-cost areas.	The most common, frequently owner-or contractor-designed. Workmanship is professional, but extras in craftsmanship not in evidence. Materials are serviceable, but built for a price. These buildings are basically little above minimum uniform building code requirements.	Above average, but not uncommon in quality of materials and workmanship. Architects and reputable contractors are retained for this work. May be considered only standard construction in high-cost areas.	Custom-built buildings, embodying superior materials and workmanship, the best normally found, though not including special construction with unusual material and labor. Well-known architects and contractors are retained for this work.	Above average quality of materials and workmanship. Architects and reputable contractors are retained for this work. Superstructure meets building codes and zoning regulations.
FOUNDATION	Granite with earth mortar	Granite with earth mortar	Granite with cement mortar	Granite with cement mortar	Granite with cement mortar	Reinforced concrete footings (M20 concrete)
SHELL SYSTEM						
Wall Material	Mud Brick	CEB	SCEB	Cement Block	Fired Clay	Reinforced concrete columns & beams (M20); Cement block infill
Electrical	No exterior lights, one interior light per room, one outlet per room, no grounding, low cost materials	Some exterior lights, one interior light per room, one outlet per room, grounded system, low cost materials	Some exterior lights, one interior light per room, multiple outlet per room, grounded system, average cost materials	Exterior lights, one light per room, multiple outlet per room, grounded system, good quality materials and fixtures	Exterior lights, one light per room, multiple outlets per room, grounded system, quality materials, custom light fixtures	Exterior lights, one light per room, multiple outlet per room, grounded system, good quality materials and fixtures
Plumbing	Plumbed cold water line and drainage; connection to water; no septic connection	Plumbed cold water line and drainage; connection to water; no septic connection	Plumbed cold water line and drainage; connection to water; no septic connection	Plumbed cold & hot water line and drainage; connection to water and septic	Plumbed cold & hot water line and drainage; connection to water and septic	Plumbed cold & hot water line and drainage; connection to water and septic
Wall Finish	Exterior & interior earth plaster	Exterior & interior earth plaster	Exterior & interior cement plaster	Exterior & interior cement plaster	Interior cement plaster	Exterior & interior cement plaster
Fenestration	One wood frame door & window per room	One wood frame door & window per room	One steel frame door & window per room	One steel frame door & window per room	One steel frame door & window per room	One steel frame door & window per room
ROOF SYSTEM	Eucalyptus-tree frame Corrugated steel covering	Milled eucalyptus frame Corrugated steel covering	Steel frame Steel covering PVC gutter system	Milled eucalyptus frame "Local" clay tile covering PVC gutter system	Steel frame Ruliba manufactured clay tile covering Steel gutter system	Milled eucalyptus frame "Local" clay tile covering (2nd Fl) PVC gutter system
FLOOR SYSTEM	Adobe	Cement Screed	Cement Screed	Limestone	Ceramic Tile	Reinforced concrete floor slabs (M20 concrete)
FINISHINGS						
Kitchen	No stove or sink	Outdoor cooking, sink, cold running water	Indoor wood stove, chimney, sink, cold running water	Indoor wood stove, chimney, sink, cold running water	Gas stove, sink, cold running water	Indoor wood stove, chimney, sink, cold running water
Bathroom	Pit latrine (includes pit, toilet stand, toilet seat), sink with fixtures, bath tray, cold running water	Pit latrine (includes pit, toilet stand, toilet seat), sink with fixtures, bath tray, cold running water	Composting toilet (includes chamber, toilet stand, toilet seat, solid/liquid waste separator, urine collection tank), sink with fixtures, bath tray, cold running water	Shared septic system, flushing toilet, sink with fixtures, bath tray, cold running water	Shared septic system, flushing toilet, sink with fixtures, bath tray, cold running water	Shared septic system, flushing toilet, sink with fixtures, bath tray, cold running water

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