Technical-economic evaluation in the use of steel containers for serial construction in social interest housing

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***Abstract*—Th Social interest housing, built in Cd. Juarez, Mexico, uses traditional methods and materials which leads to a slow development and almost a none innovation in the construction industry - resulting in a product that hardly satisfies the final user.**

The work herein exhibited present information aimed to innovate within the local industry of serial construction for social interest housing using modern construction methods (MMC). Therefore, it stablishes advantages that steel containers, reused, contribute to a construction project of this type.

The activities or tasks and the allocation of resources, cost, and time are based on a Work Breakdown Structure (WBS). An evaluation and a comparative analysis was made between the technical and economic results of the innovative system, as well as an example of a traditional project.

In addition, a life cycle analysis is proposed in order to present an approach to the effects that occur at each stage during the development for this project.

Keywords—Social interest housing, steel containers, Net present value (NPV), minimum acceptable rate of return(MARR), Modern Construction Methods (MMC).

I. INTRODUCTION (*HEADING 1*)

The serial construction of low-income housing in Ciudad Juarez, Mexico, is generally based in the use of traditional materials, labor and procedures; the prefabrication or industrialization in this type of building is practically neglected. For this construction project, it is necessary to use more efficient methods and resources, which can make more competitive the proposals of the developers and consequently benefit the final users.

There are several problems facing this type of construction, for example: a high turnover of the work force, presence of low efficiency in the use of inputs caused by the lack of adequate control, and, as well, a clear tendency to prioritize time and economy, sacrificing quality.

Another common problem, observed in this industry, is the amount of waste of materials. It represents a high percentage of the cost of the project – additionally that a few amounts of material can be recycled or reused. In addition, it must be recognized, that compared to other industries, the construction industry presents, historically, a slow technological development in materials, processes, tools, among other aspects [1].

On the other hand, it exists a housing gap, both quantitative and qualitative, that is given due to the lack of accessible and adequate housing within urban areas, as well as for the abandonment and destruction that housing have been exposed.

The aim of this paper is to analyze the feasibility of using steel containers, as raw material, in the construction industry for serial development of social interest housing, proposing a constructive process in a prefabrication and industrialization framework.

In Europe, U.S.A., and Canada the construction of houses with containers is becoming more common, students are a market for this type of houses. In Spain the cost of houses with containers is 40 percent less, this type of house has as its main advantage the sustainable development.

II. MINIMUM REQUIREMENTS FOR SOCIAL INTEREST HOUSING

Social interest housing can be divided into economic, popular, and traditional housing, depending on the square meters of construction, its average cost, and the number of rooms that comprise it [2]. However, the variable with the greatest influence on this classification is the average cost. These parameters can be observed in Table I.

Parameters that characterizes the most representative aspects within the home and within the activities for construction were identified in order to choose the most economical version of the prototype to be used in the project:

- Total area for daily activities purpose (rooms, living-dining room, kitchen, sanitary, hallways and common area).
- Total recoverable container cutting area.
- Total area of newly created walls.

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- Total length of plumbing installations

TABLE I. HOUSING CLASIFICATION BY AVERAGE COST [2].

	Economic	Popular	Traditional
Average built surface	30 m²	42.5 m²	62.5 m²
Average cost: Number of minimum wage	Less than 118	from 118.1 to 200	from 200.1 to 350
Rooms	Bathroom Kitchen Common room -	Bathroom Kitchen Living/dining room From 1 to 2 bedrooms	Bathroom Kitchen Living/dining room From 2 to 3 bedrooms

Four prototypes were conceived; a summary of the results of this review and the comparison between the various versions of the prototype are shown in Table II.

TABLE II. EVALUATION OF PARAMETERS FOR EACH PROTOYTPE.

Parameters to evaluate	Prototype			
Surface concepts (m²)	A	B	C	D
Land surface	131.20			
Housing	59.49			
Construction surface	55.45	55.66	55.69	55.31
Cutting section on containers	47.70	44.52	43.99	43.99
New walls to built	46.57	46.57	45.58	45.58
Lineal concepts (m)	A	B	C	D
Hydro-sanitary installations	53.46	55.52	50.28	38.06

Evaluating these different parameters, prototype D is identified as the most reliable, in cost terms, for its construction due to the saving in terms of the total number of hydro-sanitary installations, even if the total of newly created walls increases compared to the first prototypes – a complete calculation and allocation of costs for the preliminary review and selection of the prototype was carried out.

For the cost analysis, commercial prices of Ciudad Juarez were used. According to SAT (Mexican department of the treasury) an added (VAT) of 16% taxing for housing construction is required; therefore, following this indication, this tax was included in the price of the same. The cost per item for the D housing - container prototype was set up as follows (see Table III):

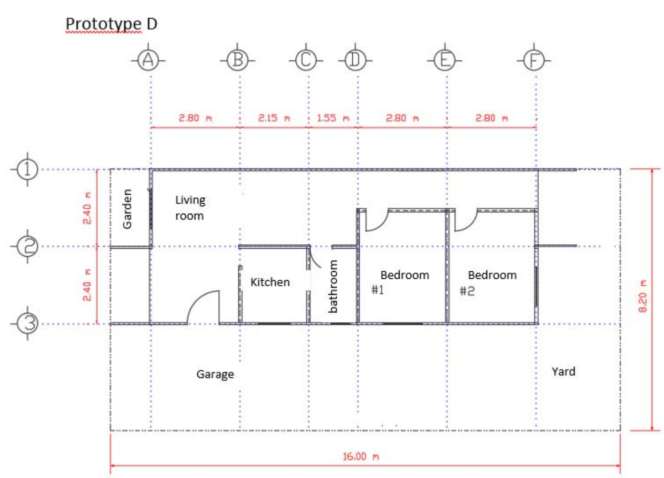
TABLE III. DIRECT COST PER CONCEPT – PROTOTYPE D.

Prototype D	
Foundation	$ 23 101.12
Housing module 1 – container D.1	$ 111 203.27
Housing module 2 – container D.2	$ 27 111.60
Exterior connections	$ 10 152.77
Maneuvers and assembly of containers	$ 16 446.53
Permanent equipment installation	$ 24 058.62
Total	$ 312 073.91

For comparison purpose, a traditional housing presents the following distribution of costs by items (see Table IV):

TABLE IV. DIRECT COST PER CONCEPT – TRADITIONAL HOUSING.

Traditional housing	
Foundation	$ 22 896.91
Structure	$ 169 114.09
Installations	$ 15 686.31
Carpentry and iron work	$ 14 849.38
Exterior connections	$ 10 147.61
Permanent equipment installation	$ 24 058.62
Total	$ 256 752.92



III. INDIRECT COST INTEGRATION

The integration of the indirect cost involves the expenses of both the central administration and the work administration operation. This project includes the salaries for professional, technical and administrative personnel, as well as the cost of maintenance and depreciation of the workshop where housing units are made, health and safety expenses, office consumables, laboratory tests, surety and insurance, signage expenses and warehouses, among others.

Table V shows the computation for each of the categories, defined by the LOPSCM regulation, for both projects.

TABLE V. FINAL COST INTEGRATION.

Cost concept	Prototype	Traditional
Direct	$ 312 073.91	$ 256 752.92
Indirect – central administration	$ 17 288.89	$ 12 914.67
Indirect – Project operation	$ 6 615.97	$ 14 557.89
Funding	$ 3 393.39	$ 8 327.81
Land surface	$ 91 266.00	$ 91 266.00
Final cost	$ 466 374.05	$ 414 625.15

IV. BALANCE POINT ANALYSIS

A first step to analyze an investment, or business opportunity, is to establish the balance point at which the project moves away from the zone of economic losses to enter the profit area – setting the number of units for which the project has a value of 0. That is, the basis on which the profits are projected and the possibility of establishing projections and goals to be achieved.

The trends computed for both, the prototype D and the traditional housing, are shown in Fig. I and II.

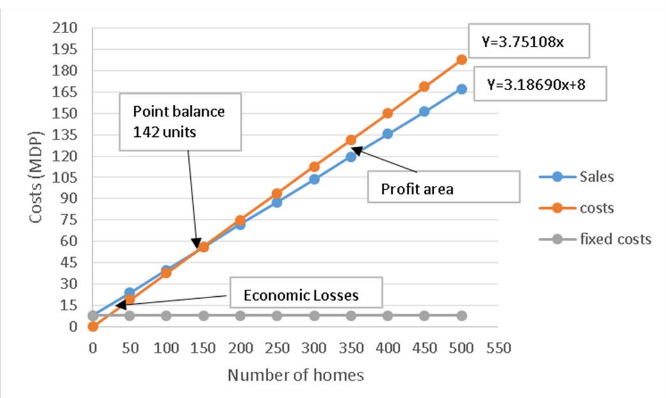


Fig. 1. Salesg-costs balance point for prototype D.

For prototype D, a base of an annual fixed cost of $ 8 022 044.96 MP is established, in addition to a variable cost per unit manufactured of $ 318 689.88 MP; finally, an estimation of the sale price of $ 375 108.05 MP is set.

Fig. I shows the trend line of "costs" and of the one for "sales"; its intersection, the equilibrium point, is defined in 142 units. This data indicates the point of entry to the profit area, or expressed otherwise, are the minimum sales required to start with the profits of the project.

In contrast, the construction of the project for traditional housing presents a fixed cost of $ 5 036 721.30 MP, a variable cost per unit built of $ 271 310.81 MP and a proposed sale price of $ 323 259.15 MP. With the straight line equations shown in Fig. II, at the intersection, a balance point of 97 units is obtained. Compared with the prototype D, in theory, we arrive in fewer units sold to the profit area. This is the first approach to the economic behavior of each of the two project options.

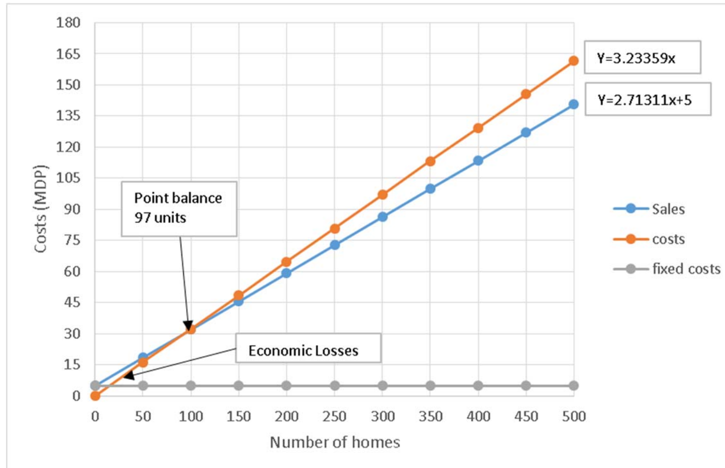
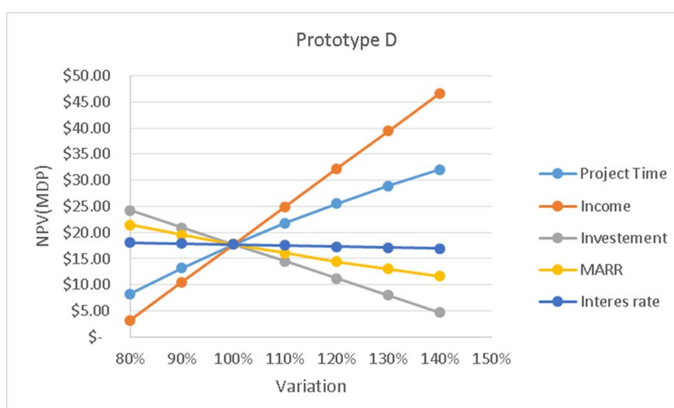


Fig. 2. Sales-costs balance point for traditional housing.

V. SENSITIVITY ANALYSIS FOR HOUSING SERIAL CONSTRUCTION PROJECT

Low-income housing traditionally, in Mexico and world widely, is produced serially; so that not a single piece is manufactured at a time, but on the contrary, developments are often assigned in several hundred houses per year. It is defined a degree of sensitivity, in terms of the net present value (NPV), for the variables in this project, being: time lapse of the project, the minimum acceptable performance rate (TREMA, in Spanish), the income expected by sales and investment in the project – these last two directly related to the number of homes manufactured per year.

The sensitivity graph is shown in Fig. III for the option to develop the new constructive method:



Sensitivity analysis for the project variables – protoype D.

Similarly, for traditional housing its sensitivity analysis is shown in Fig. IV.

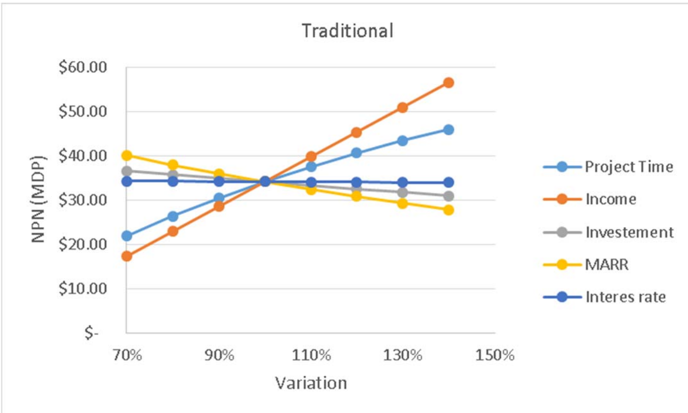


Fig. 3. Sensitivity analysis for the project variables for traditional housing.

Based on the results found, the project time and the expected income are defined as those variables that have the greatest impact on the project in terms of NPV.

The most adverse scenario for the project time variable for prototype D, where the project tends to reduce its profitability, is if it is diminished the life cycle less than 4 years – any value lower than this, under these terms, would be hardly accepted.

On the other hand, within the income, the lower limit is close to the 250 units sold. Proposing annual sales below this figure would jeopardize the profitability of the project. The variables with the lowest consequences are investment, the minimum acceptable rate of return and the interest rate related to the bank loan. However, they are indicators that management takes into account for the operation of their projects.

VI. NPV EVALUATION

Considering that the evaluation in economic terms is done in NPV terms, financial projections of the project's behavior must be established, based on the values acquired by the variables analyzed above.

These projections will be computed using random numbers that assign values to project time, income and investment. These values will depend on the probability found for each range. Accordingly, the class intervals, the probability areas and the assigned random numbers are given in Table VI.

In the same way, the data for the project is presented for traditional housing in Table VII. With the assigned random numbers, 100 iterations were made based on the values that the aforementioned variables can be, and thus obtain different projections of the NPV, and the found values were recorded, in order to establish the triangular distribution of probability with the scenarios optimistic, probable and pessimistic, for the profitability of both projects.

The financial statements were projected using the resulting data in previous sections such as project time, investment, income, fixed and variable costs, as well as depreciation, financial products, profits and taxes, among others.

TABLE VI. DISTRIBUTION FOR CLASS INTERVALS FOR EACH VARIABLE FOR PROTOTYPE D

Prototype						
Time						
Class intervals		Area	Accumulated	%	Random values	
5.00	6.60	0.1070	0.1070	11%	0.00	10
6.60	8.20	0.3170	0.4240	42%	11.00	41
8.20	9.80	0.3200	0.7440	74%	42.00	73
9.80	11.40	0.1920	0.9360	94%	74.00	93
11.40	13.00	0.0640	1.0000	100%	94.00	100
Sales						
Class intervals (MDP)		Area	Accumulated	%	Random values	
$139.165	$154.843	0.0920	0.0920	9%	0.00	8.0
$154.844	$170.523	0.2670	0.3590	36%	9.00	35
$170.524	$186.202	0.3490	0.7080	71%	36.00	70
$186.203	$201.882	0.2210	0.9290	93%	71.00	92
$201.883	$217.562	0.0710	1.0000	100%	93.00	100
Investment (MDP)						
Class intervales		Area	Accumulated	%	Random values	
$ 22.251	$ 23.239	0.0820	0.0820	8%	0.00	7.0
$ 23.240	$ 24.228	0.2370	0.3190	32%	8.00	31.
$ 24.229	$ 25.216	0.3640	0.6830	68%	32.00	67
$ 25.217	$ 26.205	0.2370	0.9200	92%	68.00	91
$ 26.206	$ 27.195	0.0800	1.0000	100%	92.00	100

The random numbers were related to the flow runs in the financial statements for the elaboration of different scenarios and thus form the universe of values that will shape the probability distribution in terms of the NPV.

TABLE VII. DISTRIBUTION FOR CLASS INTERVALS FOR EACH VARIABLE FOR TRADITIONAL HOUSING.

Traditional housing						
Time						
Class interval		Area	Accumulated	%	Random numbers	
3.00	5.00	0.080	0.0800	8%	0	7
5.00	7.00	0.240	0.3200	32%	8	31
7.00	9.00	0.360	0.6800	68%	32	67
9.00	11.00	0.240	0.9200	92%	68	91
11.00	13.00	0.080	1.0000	100%	92	100
Sales						

Class interval (MDP)		Area	Accumulated	%	Random numbers	
$ 50.444	$ 69.456	0.050	0.0500	5%	0	4
$ 69.457	$ 88.470	0.151	0.2010	20%	5	19
$ 88.471	$107.483	0.251	0.4520	45%	20	44
$107.484	$126.497	0.351	0.8030	80%	45	79
$126.498	$145.511	0.197	1.000	100%	80	100

Investment

Class interval (MDP)		Area	Accumulated	%	Random numbers	
$ 5.513	$ 5.757	0.081	0.081	8%	0.0	7
$ 5.758	$ 6.002	0.235	0.316	32%	8	31
$ 6.003	$ 6.247	0.366	0.682	68%	32	67
$ 6.248	$ 6.492	0.236	0.918	92%	68	91
$ 6.493	$ 6.738	0.082	1.000	100%	92	100

As a comparative analysis, the ranges in millions of pesos for the NPV and their probability of occurrence are presented in Table VIII.

In the case of the prototype, the probability density reaches its highest point (0.1700) in the range between 15 to 20 million pesos, while on the other side, in the NPV for the traditional case, the highest value (0.1800). manages to reach the range of 20 to 25 million pesos. As observed, around these values will be grouped the highest probability of occurrence for each case. Therefore, there is a greater probability that the project executed through the traditional method will be more profitable than its counterpart made by the new method.

Although the values of the NPV for the project based on the prototype can reach almost 55 million pesos, a situation that its counterpart does not contemplate, it is also true that negative figures may be more adverse than the traditional project. When reviewing the three variables evaluated, in order to measure the project in terms of NPV, it is observed that for the option of the prototype D manufacturing project, it is required a greater time lapse, at least of 5 years, a projected annual sales of 370 homes approximately and an investment of $ 22 251 164.40 as a starting point.

The cost per finished unit of the prototype D is above the cost per finished unit of traditional housing.

TABLE VIII. PROBABILITY FOR EACH VPN RANK.

Rank (millions, NPV)		Probability		Accumulated	
		Prototype	Traditional	Prototype	Traditional
-5	0	0.0050	0.0010	0.0050	0.0010
0	5	0.0460	0.0280	0.0510	0.0290
5	10	0.0950	0.0700	0.1460	0.0990
10	15	0.1440	0.1120	0.2900	0.2110
15	20	0.1700	0.1540	0.4600	0.3650
20	25	0.1490	0.1800	0.6090	0.5450
25	30	0.1250	0.1530	0.7340	0.6980
30	35	0.1010	0.1200	0.8350	0.8180
35	40	0.0770	0.0900	0.9120	0.9080
40	45	0.0530	0.0600	0.9650	0.9680
45	50	0.0290	0.0290	0.9940	0.9970
50	55	0.0060	0.0030	1.0000	1.0000

VII. CONCLUSIONS

The prototype herein presented, prototype D, is in the market price limits for a popular housing, as indicated by the National Housing Information and Indicators System (SNIIV) [3]. The reduction of the manufacturing or construction time, per piece, is approximately 60% compared to the traditional method.

Usually, this type of housing is manufactured in series, or by stages, as they are known in the region. However, elaborating each housing unit at the factory, reduces the possibility of the existence of lost days of work due to weather effects and other setbacks present in the traditional method.

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