The Emerging Constraints in the Implementation of Prefabrication for Public Housing in the Philippines using Principal Component Analysis

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Abstract
The practice of prefabricated construction has been proven effective due to its numerous advantages, such as onsite construction risk reduction, cost-effectiveness, and efficient construction process. Globally, the role of prefabrication is to improve sustainability and the economic aspect of the construction industry. The Philippines is still adapting to prefabrication and needs more studies regarding the constraints in developing prefabrication in the country. Moreover, public housing projects in the Philippines need to be more proficient due to the neglect of the local governments. The main objective of this paper is to identify the limiting factors in implementing prefabrication on mass housing production in the Philippines. Twenty variables contribute to the hindrances of the development of prefabrication gathered through past related studies. A survey questionnaire was distributed among engineers, designers, property managers, and contractors. A total of 52 responses were collected through google forms. Twenty variables were ranked according to their mean scores after an Analysis of Variance (ANOVA) determined no statistically significant differences between the data from the four stakeholders. To reduce the dimensionality, five limiting factors were identified from a Principal Component Analysis (PCA): Knowledge and Experience, Cost, Risk, Industrial Chain, and Social Climate. High Initial Cost was the most influential variable determined by the mean scores. The government should first provide subsidies to encourage production and consumption in the building sector. When this is implemented, it enables the production of more services and goods.

Keywords
Prefabricated Construction, Public Housing, Constraints, Advantages, Philippines

1. Introduction

The prolonged housing crisis is one of the most pressing concerns in the Philippines' construction industry (Oxford Business Group, 2022). The housing backlog is expected to rise to over 22 million units by 2040 if no solution is implemented and given with only 0.74 percent of the budget, as stated by San Jose del Monte City Rep. Florida "Rida" Robes. In addition, Elsie Trinidad from the National Housing Authority said that housing in the Philippines is budget-dictated. Sometimes, it needs to meet the goal since it competes with other priorities and fundamental sectors. With that said, this study will be associated with public housing which the researchers define as a government mass housing production. Moreover, it aims to address this concern by implementing prefabrication as an ideal way to produce mass houses efficiently.

Prefabrication can significantly reduce construction costs, as Gupta et al. (2018) found that prefabrication is a cost-effective and environmentally friendly method that might be used to provide affordable homes. However, despite all promising features, constraints can exist during its initial stages of adoption. In a study by Jiang, et al. (2018), four factors were found: the industrial chain, cost, social climate, attitude, and risk. A survey and semi-interview were conducted among groups; contractors, engineers, developers, designers, property managers, and component producers, and it was discovered that the industrial chain is an essential factor influencing the promotion of prefabrication in China.

In the Philippines, only some types of prefabrication are guaranteed since, in the conventional sense, it needs large amounts of heavy transportation, cranes, and modern infrastructure, which is not primarily available in the country. As a result, the most practical use is prefabricated components, which can be handled without heavy equipment (Schaik, 2016). Prefabrication slowly adapted and evolved, and various developers and construction companies started offering prefab services and houses. Good services available in the country are the CUBO Modular, Bahay Makabayan Modular & Prefab, Prefab Homes PH by Top-Notch Construction, Indigo Prefab House, SmartHouse Philippines, Prefab PH, MyHouse Philippines, WallCrete, and Nest Box Philippines. The mentioned have in common in offering affordable instant installation.

Prefabrication technology and low-cost housing construction exhibit a strong correlation, which justifies integrating them; thus, with the growing need for large-scale affordable housing, prefabricated building presents a significant opportunity to promote (Zhou, et al., 2018). According to Almarwae and Ganiron (2014), prefabricated components may significantly reduce construction costs, resources, and time; thus, prefabricated housing seems to be a practical option for the Philippine government to address the country's high-cost housing need without sacrificing quality. Prefabrication is indeed a sustainable approach that is an ideal solution to provide housing, given that it is cost-effective and provides urgency to build, especially during post-calamities.

However, the adoption of prefabs in the country is still in its initial stage, so it still needs to be widely promoted. Hence, this study tackled the factors that influence the promotion of prefabrication—furthermore identifying the limiting factors that hinder the locals from utilizing the said technology to assist the stakeholders in the construction industry and prefab experts in addressing this issue.

2. Methodology

2.1 Methodological Framework

This study followed a framework consisting of 5 phases: literature review, questionnaire formulation, data collection, data analysis, and result conclusion. This is shown in Figure 1.

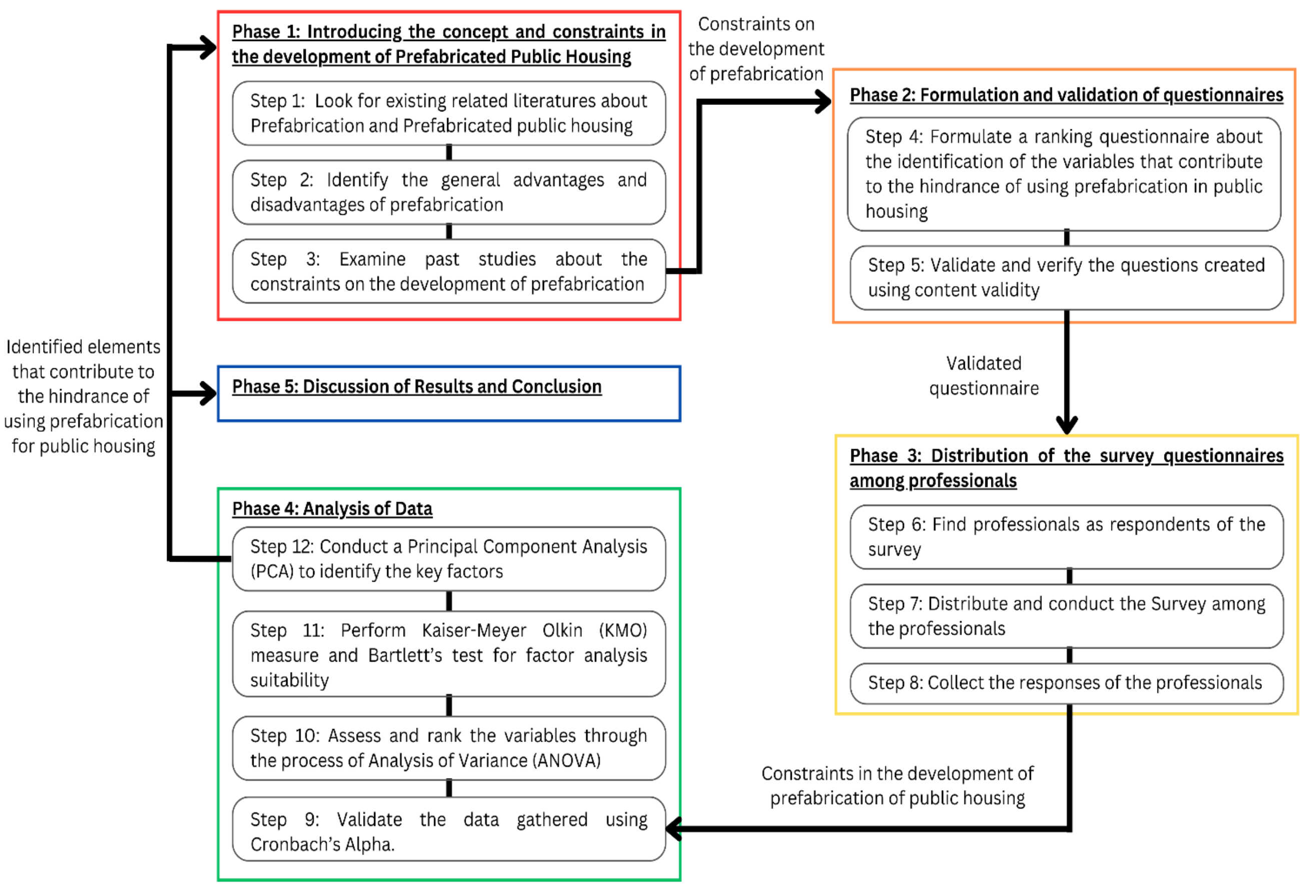

Fig. 1. Methodological Framework

2.2 Statistical Treatments

Statistical treatments were ideal for this study in analyzing and determining the significance of the variables and differences among the stakeholders' groups as the study's respondents. Cronbach's Alpha is used as a reliability test to evaluate the constancy and consistency of the collected data. The range of Cronbach's Alpha is -1 to 1. A negative value suggests that the data is inaccurate. A result between 0.6 and 0.8 is considered satisfactory, while a value between 0.80 and 0.90 indicates that the data obtained from the survey questionnaire is highly reliable.

Once the data were validated, a statistical approach known as Analysis of Variance (ANOVA) was used to enable researchers to evaluate the significance of group differences and the associated methods. The researchers utilized ANOVA to assess whether there was a statistically significant difference between the variable scores from the various groups. This will be confirmed using the resulting ANOVA p-value. An ANOVA p-value of less than 0.05 indicates a statistically significant difference between the groups, while ANOVA p-value values greater than 0.05 means no statistically significant difference between the groups. The researchers also used the mean score approach to evaluate the components' overall relevance. If multiple factors have the same mean score, the factor with the lowest standard deviation (SD) will be ranked higher.

Principal Component Analysis (PCA) is a multivariate statistical analysis approach involving a linear transformation to extract significant variables. The researchers performed PCA since the questionnaire is composed of different measures. Some of them can be related to a specific characteristic. Factor analysis is proposed to determine the variability and correlation of these variables.

Kaiser-Meyer-Olkin (KMO) of Sampling Adequacy and the Bartlett Test of Sphericity are initially applied to the data before performing PCA. Both tests are performed to see if the variables may be used in factor analysis. In addition, this verifies a stand on the research hypothesis.

The researchers used IBM SPSS Statistics 25 in analyzing the data gathered from the respondents to the survey questionnaire. With the help of this tool, tabulated reports, charts, plots of distributions and trends, descriptive statistics, and sophisticated statistical analyses can all be produced using data from different kinds of files. In the case of the researchers, they performed various statistical treatments for this study, such as Cronbach's Alpha for reliability test, ANOVA for identifying the significant difference among various groups of stakeholders, and PCA including KMO and Bartlett's test for factor analysis.

3. Results

3.1 List of Variables

The variables used were initially labeled with codes in the survey questionnaire to simplify the items in the statistical treatments. The list of variables with their codes is presented in Table 1.

Table 1. List of Variables

Code	Variables
V1	Lack of Comprehensive Understanding of Prefabricated Construction
V2	Lack of Relative Policies, Laws, and Standards
V3	Disapproval by the Market
V4	Quality Problems Due to the Excessive Pursuit of Assembly Rate
V5	High Cost Due to Discordant Scale
V6	Unintegrated Industry Chain
V7	Potential Costs Increased Due to Uncertainties
V8	High Initial Cost
V9	Higher Average Cost Compared to Traditional Building
V10	Potential Delays of Manufacturers’ Limited Capacity
V11	Lack of Durability, Leakage, and Cracks
V12	Insufficient Construction Capacity
V13	Lack of Well-Developed Technical System
V14	Lack of Research & Development Input
V15	Insufficient Integrated Design Capacity
V16	Low-Level of General Contracting
V17	Lack of Practice and Experience
V18	Lack of New Management Method for Prefabricated Construction
V19	Lack of a Synergetic Information Platform
V20	Long Design Time

3.2 Result of Analysis of Variance (ANOVA)

Before utilizing the collected data for data analysis, the researchers conducted a reliability test to validate the consistency and constancy of the data gathered. Cronbach's Alpha validated the respondents' responses on the 20 variables. From the table, the result shows 0.878, which ranges from 0.8-0.9, which typically implies that the data gathered from the survey questionnaire is immensely reliable.

Table 2 shows a ranking of the mean score of the 20 variables. Two variables (V8 and V17) scored above four and are classified as agreed to be necessary, while the other variables scored above three and were perceived as neutrally necessary. The variable V8, "High Initial cost," has the highest mean score of 4.17 and has a standard deviation of 0.81. Thus, the V8 is perceived by the stakeholders as the main factor influencing the implementation of prefabrication on public housing in the country. Moreover, following the V8 are the V17 (Lack of Practice and Experience), V4 (Quality Problems Due to the Excessive Pursuit of Assembly Rate), V7 (Potential Costs Increased Due to Uncertainties), and V18 (Lack of New Management Method for Prefabricated Construction).

Table 2. ANOVA Results

Variable	Mean					Overall Standard Deviation	Rank	F	P
	3	6	37	6	52				
	Contactors	Designers	Engineer	Property Manager	Overall				
V1	4	3.33	3.97	3.67	3.87	0.95	6	0.887	0.455
V2	3	3.33	4	3.33	3.79	1.016	9	2.059	0.118
V3	3.33	2.5	3.62	3.5	3.46	1.056	18	2.082	0.115
V4	3.33	3.67	3.95	4.17	3.9	0.869	3	0.782	0.51
V5	3.67	3.17	3.92	3	3.71	1.035	13	2.127	0.109
V6	3.67	3.33	3.86	3.83	3.79	0.667	8	1.146	0.34
V7	3.67	4.17	3.95	3.5	3.9	0.955	4	0.58	0.631
V8	3.67	3.67	4.35	3.83	4.17	0.81	1	2.283	0.091
V9	3.67	3.5	3.81	3.17	3.69	1.076	14	0.678	0.57
V10	3.67	3.5	3.97	3.33	3.83	0.985	7	1.022	0.391
V11	4	2.83	3.24	3.33	3.25	1.203	20	0.625	0.602
V12	3.33	3.67	3.54	3.67	3.56	0.978	16	0.1	0.959
V13	3.33	3.67	3.81	3.67	3.75	0.813	10	0.359	0.783
V14	3.33	3.17	3.84	3.5	3.69	1.094	15	0.841	0.478
V15	3	3	3.68	3.33	3.52	1.038	17	1.101	0.358
V16	3.67	3.17	3.86	3.33	3.71	0.776	12	2.071	0.116
V17	3.67	4	4.24	3.83	4.13	0.886	2	0.73	0.539
V18	3.33	3.67	3.95	3.83	3.87	0.817	5	0.651	0.586
V19	3.67	3.67	3.89	3	3.75	0.883	11	1.881	0.145
V20	3	3.83	3.27	2.83	3.27	1.105	19	0.886	0.455

3.3. Result of Principal Component Analysis (PCA)

Kaiser-Meyer-Olkin (KMO) of Sampling Adequacy and the Bartlett Test of Sphericity were performed before beginning the Principal Component Analysis to determine whether the data collected was appropriate for factor analysis. The result shows that the KMO of Sampling Adequacy of the data is 0.681, which can be considered acceptable and exhibits a correlation between variables, and is a satisfactory fit for factor analysis. While there is 0 significance for Bartlett's Test of Sphericity, which implies that the correlation matrix is not an identity matrix, rejecting the null hypothesis and factor analysis is possible.

Principal Component Analysis was then conducted, and there were 6 factors extracted with a 73.95% cumulative variance. Based on the result, V3 has shown the most negligible value in some aspects to be considered significant. Thus, the V3 was eliminated, and another round for PCA was conducted.

Similar to the previous method, the new data set undergoes another KMO measure and Bartlett's test. The resulting KMO measure is 0.71, which is also in a range that is acceptable and shows the correlation among variables. Bartlett's test result has a 0 significance level, indicating that the data are suitable for factor analysis and rejects the null hypothesis.

Table 4 presents the result of a rotated component matrix from the second PCA; 5 factors were extracted from 20 variables with 69.675% of the variance. The items V19, V17,18, V16, and V14 are clustered to Factor 1. For cluster 2, these are the items V9, V8, V10, V5, and V7. While the variables V12, V11, V13, V20, and V15 are clustered for factor 3. The items V1 and V2 are for factor 4. Lastly, the variables V6 andV4 for the fifth factor. The summary of PCA results is presented in Table 5.

Table 3. First Factor Analysis Rotated Component Matrix

Variable	Factors						Communality
	1	2	3	4	5	6	
V17	0.844	0.029	0.161	0.03	0.039	0.079	0.747
V19	0.841	0.204	0.087	-0.057	-0.006	0.016	0.76
V18	0.747	0.304	0.096	0.176	0.15	-0.075	0.719
V16	0.67	0.154	-0.126	0.169	0.221	0.203	0.607
V12	0.15	0.876	0.012	0.05	0.135	0.178	0.843
V11	0.337	0.707	0.245	-0.086	-0.293	0.043	0.768
V13	0.377	0.692	-0.006	0.224	0.073	-0.236	0.732
V20	-0.04	0.664	0.268	-0.275	0.177	0.025	0.622
V15	0.396	0.629	-0.085	0.326	0.416	-0.013	0.84
V19	-0.062	0.05	0.846	0.147	-0.083	-0.092	0.76
V8	0.135	-0.031	0.775	0.244	0.165	0.266	0.777
V10	0.074	0.24	0.675	0.099	0.133	0.288	0.629
V5	0.121	0.11	0.667	0.16	0.463	-0.141	0.732
V7	0.454	0.13	0.538	-0.181	0.155	-0.472	0.793
V1	0.051	0.071	0.168	0.815	0.158	0.045	0.727
V20	0.086	-0.12	0.365	0.78	-0.016	0.148	0.622
V14	0.447	0.376	-0.059	0.456	0.173	-0.402	0.744
V6	0.113	0.098	0.145	-0.056	0.802	-0.049	0.692
V4	0.144	0.085	0.15	0.325	0.711	0.252	0.725
V3	0.374	0.175	0.267	0.178	0.182	0.695	0.79
Eigenvalues	3.495	3.04	2.984	2.076	1.913	1.282	
% of Variance	17.474	15.198	14.92	10.38	9.567	6.409	
Cumulative %	17.474	32.672	47.592	57.975	67.542	73.95	

Table 4. Second Factor Analysis Rotated Component Matrix

Variable	Factors					Communality
	1	2	3	4	5	
V19	0.833	0.098	0.188	-0.068	-0.017	0.744
V17	0.828	0.172	0.014	0.028	0.031	0.717
V18	0.765	0.107	0.294	0.133	0.139	0.72
V16	0.655	-0.105	0.15	0.196	0.227	0.552
V14	0.524	-0.057	0.378	0.346	0.157	0.565
V9	-0.047	0.842	0.043	0.119	-0.097	0.737
V8	0.11	0.786	-0.036	0.28	0.165	0.737
V10	0.048	0.695	0.233	0.153	0.135	0.581
V5	0.148	0.669	0.104	0.095	0.445	0.688
V7	0.501	0.529	0.111	-0.298	0.117	0.646
V12	0.143	0.03	0.875	0.056	0.137	0.809
V11	0.326	0.249	0.696	-0.102	-0.304	0.755
V13	0.424	-0.001	0.69	0.143	0.058	0.68
V20	-0.039	0.285	0.656	-0.265	0.169	0.611
V15	0.426	-0.066	0.632	0.286	0.414	0.839
V1	0.088	0.179	0.085	0.806	0.168	0.725
V2	0.1	0.373	-0.11	0.796	-0.005	0.794
V6	0.13	0.16	0.095	-0.081	0.794	0.689
V4	0.135	0.169	0.091	0.336	0.72	0.687
Eigenvalues	3.499	2.977	2.96	1.984	1.856	
% of Variance	18.417	15.668	15.579	10.442	9.769	
Cumulative %	18.417	34.085	49.664	60.105	69.875	

Table 5. Summary of Results

Factor	Variables
Knowledge and Experience	Lack of a Synergetic Information Platform
	Lack of Practice and Experience
	Lack of New Management Method for Prefabricated Construction
	Low-Level of General Contracting
	Lack of Research & Development Input
Cost	Higher Average Cost Compared to Traditional Building
	High Initial cost
	Potential Delays of Manufacturers' Limited Capacity
	High Cost Due to Discordant Scale
	Potential Costs Increased Due to Uncertainties
Risk	Insufficient Construction Capacity
	Lack of Durability, Leakage, and Cracks
	Lack of Well-Developed Technical System
	Long Design Time
	Insufficient Integrated Design Capacity
Social Climate	Lack of Comprehensive Understanding of Prefabricated Construction
	Lack of Relative Policies, Laws, and Standards
Industrial Chain	Unintegrated Industry Chain
	Quality Problems Due to the Excessive Pursuit of Assembly Rate

4. Discussion of Results

Factor 1: Knowledge and Experience

In the Philippines, there has yet to be much-prefabricated construction developed. Several challenges inhibit the industry's continued development in construction, design, technology, scale, experience, and other areas. Current construction companies need to explore alternative frameworks thoroughly and are often cautious about investing significantly in new technology and equipment, resulting in the need for a well-developed system design. Lack of contractors' experience, inflexibility to design changes, and familiarity and knowledge about prefabrication are barriers to construction (Razkenari, M. et al., 2019). The government should consider a systematic classification and integration of previous studies about prefabrication to fully understand and comprehend the impacts on the construction industry in the Philippines.

The Philippines is still in its first phase of implementing new technologies in the construction industry, which needs a competitive market for new construction methods. Most engineers and developers are still choosing traditional construction over new technology. However, this is expected to change as the construction industry develops.

Factor 2: Cost

From the production stages to the transportation stage of prefabrication, prefabricated components are more expensive than traditional construction (Jiang et al., 2020). In the prefabrication process, construction industries should provide storage facilities to keep prefabricated components and sections of any type and size safe from the elements and the weather. Construction personnel must get specific training at prefabricated manufacture and assembly and onsite installation facilities before employing specialized equipment and tools for prefabrication. They must have learned how to handle new products and machinery and coordinate, monitor, and supervise a construction project.

In addition to the high initial cost, training, module transportation to the site, component expenses, and equipment expenses are too expensive. However, cost should be one of many considerations when choosing a building technique. Quality, punctuality, and environmental concerns must all be taken into account.

Factor 3: Risk

Due to insufficient technology that imposes risks on the quality of construction, the prefabricated building sector has remained inappropriate, given the situation in the Philippines. Material strength, unstable joints, and fractures in critical locations are all problems brought on by underdeveloped technology and unskilled workers. Stakeholders may not be interested in prefabricated buildings since resolving these problems could be extremely expensive. Designers should always verify the material strength to ensure it meets standards to mitigate these risks and minimize the problems that may arise during prefabrication and assembly.

The underdeveloped market has also created a need for more prefabricated component manufacturers. Manufacturers typically need help to satisfy growing market demand due to limited production capacity and design for large projects. This raises the possibility of delays that could throw off the schedule for the entire construction project. Prefabrication companies are urged to increase component manufacturing to address the component shortages, which would pave the way for more industry and market collaboration.

Factor 4: Industrial Chain

A well-rounded industrial chain is essential for new construction methods where technology significantly implements new ideas. Due to the lack of comprehensive understanding of the new construction methods, lack of practice and experience, and lack of competence, construction industries often disapprove and stick to their original or traditional ways. In the construction industry, for example, preliminary design for buildings, components, equipment, and installation process these problems in succeeding stages of construction, resulting in cost changes and progress delays.

In an assembly process, prefabricated construction is more complicated than traditional construction, resulting in a lack of construction capacity. Due to design problems, the main structure is complicated to join, making it a top priority for improvement.

Factor 5: Social Climate

Many construction industries still use the onsite construction method in the Philippines, despite knowing that prefabrication has been in the construction market for so long. Numerous construction industries need to gain systematic knowledge and comprehension of prefabricated construction regarding its safety, durability, and the relative policies and standards circling this technology. Additionally, companies involved in the design, manufacturing of modules and components, construction, and assessment of the final product need to familiarize themselves with this prefabrication construction method which shows a lack of comprehensive understanding and a lack to adapt other technologies appropriately.

5. Conclusions

The Philippines has begun slowly adapting the concept of prefabrication technology in construction practices. However, this prefabrication is only applied to limited capacities. According to the related studies, it mostly gathered favorable characteristics that can benefit public housing. This study has collected variables limiting prefabrication usage from related studies for survey questionnaires. 52 respondents participated in the collection of data, and these respondents were composed of different groups of stakeholders such as contractors, designers, engineers, and property managers. The data gathered were validated and treated with statistical treatments. There were no statistical differences according to ANOVA results on the mean scores of the data collected from these groups of stakeholders. According to the mean scores, the top variable was "High Initial Cost," followed by "Lack of Practice and Experience," "Quality Problems Due to the Excessive Pursuit of Assembly Rate," "Potential Costs Increased Due to Uncertainties," and "Lack of New Management Method for Prefabricated Construction." KMO measures and Bartlett's test were applied to the variables, showing that correlation exists among the variables, which rejects the study's null hypothesis and exhibits a satisfactory factor analysis. Thus, these variables were extracted into 5 factors through Principal Component Analysis. The identified five factors are "knowledge and experience," "cost," "risk," "industrial chain," and "social climate." The results of this study are an essential reference for introducing prefabrication in the Philippines' construction industry, specifically in implementing this technology in local public housing projects.

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