Permanent Housing for Seasonal Workers? A Generalized Peak Load Investment Model for Farm Worker Housing

Elvis Qenani-Petrela, Ron Mittelhammer, and Philip Wandschneider

Many seasonal workers are housed in transitory accommodations, including tents and vehicles. In this study, we analyze the supply side of this problem by assuming that a public agent must house the workers through direct public investment. A peak load model is adapted to develop investment rules for the least-cost provision of seasonal worker housing, adding an interacting multi-season component to existing models. Based on this model and the data from three prototype projects, the majority of the least-cost investment would be in permanent, but seasonally occupied, housing.

Key Words: farmworker housing, investment rules, peak load model, public housing, seasonal labor

JEL Classifications: R31, H75, J43, G31

Many industries rely on inputs that have large swings in seasonal usage. For example, agriculture, tourism, fishing, and logging all depend on seasonal labor. Where input supply is flexible, the industry can adapt to seasonal variations in demand and input prices. However, a "peak load problem" can emerge if certain rigidities exist. The peak load investment problem was first analyzed in energy markets, where demand fluctuates significantly. Since electrical energy is difficult to store on a large scale, energy capacity must be built to supply all levels of demand, including the highest (peak load), instantaneously, or grave consequences occur—brownouts and blackouts. However, maintaining capacity to meet peak loads leaves idle an excess supply capacity at nonpeak times. Hence, underutilized off-peak capacity is consistent with efficiency—if it is the least-cost solution to the peak load problem. The peak load investment problem concerns determining the least cost mix of capacity types used to meet market requirements, including how much of the capacity requirement should be met by "base capacity"—characterized by high investment cost and low operating cost—versus "on-demand" or emergency capacity—characterized by low investment cost and high operating cost.

The provision of housing for seasonal labor is analytically similar to the energy case. Ignoring the considerable social dimensions for the moment, the problem of providing housing for seasonal workers is, roughly speaking, a peak load "storage problem." As with energy, seasonal labor has great variability and supply must always balance demand;

Elvis Qenani-Petrela is assistant professor, Agribusiness Department, California Polytechnic State University, San Luis Obispo, CA. Ron Mittelhammer and Philip Wandschneider are professors, School of Economic Sciences, Washington State University, Pullman, WA.

Table 1. Summary Statistics for the Washington State Farm Workers, Off- and Peak-Season Demand, Years 1994–1998 and 2000–2005

	Off-Season Demand (November–April)		Peak-Season Demand (May–October)	
Period	Mean	SD	Mean	SD
1994–1998	18,707.1	5,728.9	54,990.7	13,577.6
2000–2005	14,446.5	4,648.0	45,168.6	11,785.9

Source: Washington State Employment Security Department (WAESD).

workers must live (sleep, be "stored") somewhere. Again, while total "housing capacity" must meet peak housing demand, housing capacity may be idle or underutilized in the off-season.

Seasonal labor in agriculture epitomizes these issues in many parts of the United States. Producers and state employment officials continue to report that they are concerned with whether there will be sufficient supplies of seasonal workers to harvest and tend to the agricultural crops (Thilmany and Miller; Labor Market Information).

For instance, in Washington, the large presence of the apple and cherry industries contributes to a persistent and large seasonal swing in labor demanded, both among and within years. Demand for workers increased as the Washington industry expanded through the 1990s and peaked in 1998. Currently, employment levels are stable to slightly lower, though they remain above pre-1990 levels. Data on the levels of hired workers from 1994 to 2005 are reported in Table 1.

While some farm workers are drawn from local populations, most of the seasonal labor supply in Washington is provided by a continuing flow of migrant workers who have no permanent local residence. In particular, a large part of the field workforce is supplied by undocumented international migrants, generally from central Mexico. In informal conversations with the authors, employers and their representatives indicated that provision of housing has been a pertinent nonwage strategy in helping growers meets their labor demands. For instance, one large landholder in Washington maintained the infrastructure for what was essentially a private seasonal "campground" for his core workers. Many of his workers were international migrants who returned to his farm every year. While such farmer-supplied housing is a feature of the overall seasonal labor market structure, it is not a general practice, presumably because most laborers work on several farms.

While the research presented here concentrates on the supply of housing for seasonal labor, the problem of housing migrant workers is linked to other current regional and national issues. Legal and illegal immigration is a prominent and persistent national issue. The United States and its economic base was, and continues to be, built on immigration—free, indentured, and slave; legal and illegal; European, African, and Latin American; and so on. While immigrants help build the economy, they also place demands on the social and economic infrastructure, leading to policy challenges. Current specific policy issues include legal residency (amnesty) for current illegal or undocumented immigrants; guest worker programs for temporary workers; education for immigrants and their dependents; language and cultural assimilation; participation in health, retirement, and other social programs; and impact on nonimmigrant job opportunities and wages.

Housing, then, is just one of many interrelated issues that stem from the continuous influx of an immigrant workforce, including a seasonal workforce. Changes affecting any one issue can have unexpected and unintended impacts on others. For instance, type and location of housing can affect: availability and timing of work, access to education and child care, access to social services, and social and aesthetic aspects of neighborhoods. Therefore, the market that generates the demand for seasonal worker housing could affect—and be affected by—any of the three major themes found in current policy discussions: increasing guest worker programs, legalizing the residency status of many currently undocumented immigrants, and strengthening the enforcement of immigration laws.

Even when one tries to restrict the discussion to the housing issue, one finds a complex, multidimensional problem. On the "demand" side, stakeholders include, but are not limited to, workers and their dependents. For workers, "standard" housing is very expensive relative to wages. Moreover, the seasonal workers labor pool includes several subgroups ranging from local residents to international migrant workers. In particular, the international workers are more interested in saving a high portion of wages for remittances home than in making a long-term housing investment in the United States. Therefore, for many, if not most, workers, housing is a day-to-day decision problem rather than a durable goods investment problem.

Employers are also stakeholders. Individually and collectively, workers' housing is part of the package that attracts and retains workers. In particular, housing proximity can affect worker availability. Another stakeholder is the local community. Housing location affects costs of providing education, child care, and social services. Also, housing for low-paid and temporary residents is often associated with negative public health, aesthetic, transportation, and infrastructure spillovers. Finally, society as a whole may have social preferences over the well-being of workers, farmers, and associated industries, and the local community residents. Hence, the state may take a direct interest in housing based on a variety of concerns, such as the strength of the industry that employs the workers, the health of the local workers, and the social infrastructure of the region.

Generally in the United States, purchasing housing is an individual responsibility within a housing market that is mostly private (albeit with many government activities). Indeed, many seasonal agricultural workers participate in the local real estate market. However, this self-provision sometimes spills over into the use of old cars and legal and illegal campgrounds or substandard apartments. As previously noted, these alternatives may be financially sensible for the workers, but they are likely to generate negative externalities.

Another alternative is to view housing as part of the employer's compensation package. Indeed, in the general economy employers provide housing for many seasonal jobs and/or remote work locations—for example, dude ranches, forest workers, and oil production sites. However, the nature of seasonal farm work is such that often a laborer will work at many locations and for many employers during the season. Therefore, employers have low incentives to provide housing for transitory seasonal workers, especially for those who might be working for competitors.

Given spillover effects on the local community and the impact on industry, perhaps it is not surprising that the state becomes a third participant in the seasonal worker housing market. State participation can take the form of subsidies to the local housing market (e.g., rooms at local apartment complexes) or of more direct investment in state-sponsored housing projects. State participation brings public choice and political economy issues into the overall question. In summary, the seasonal worker housing market is a multi-segmented economic sector characterized by mixed public-private-employer ownership and decision-making patterns.

Regarding the scope of the housing issue, consider again the case of the state of Washington. According to estimates from the Department of Health in the state of Washington, the annual total number of farm workers is approximately 60,000. Of these, more than 37,000 workers, or about 60% of the total workforce, were found to lack regular housing during the growing season (LMI, 2002). Furthermore, another 120,000 members of workers' households (seasonal workers and their dependents) live in inadequate housing (WSOCD). Other states in the West, the Southeast, and even the Midwest face similar problems. Housing throughout the West and Southeast is often scarce and expensive.

A complete analysis of the housing market for seasonal workers would require a model that accounts for the endogeneity of labor and housing markets, the diversity of housing market segments, and all the ownership and decision-making patterns previously noted. In this paper, we make a number of simplifying assumptions that allow us to focus on one prominent feature of the market. We take the stochastic need for housing capacity as a given and analyze the peak load investment problem to provide for this housing demand. One concern is possible structural changes in this market. For instance, there is a trend towards the substitution of capital for labor. Other changes could be caused by changes in immigration policy. However, without information about the potential impacts of these changes, we can not directly examine them, although we can do sensitivity analysis to provide some perspective on the relative stability of our results.

Collecting the observations to this point, we note that: 1) migrant workers are temporary residents who can pay very little rent and often live in substandard and unhealthy housing; 2) migrant housing often creates significant negative neighborhood spillovers; and 3) growers individually and collectively have an interest in providing housing to recruit labor, but high costs and liabilities are expensive relative to the individual private returns for attracting short-term labor (LMI, 2002). Thus in Washington, the state is actively involved in providing the major increments to housing, often by financing community projects. Similar policy discussions and government actions can be seen in other states, including Florida, California, and Michigan (Goodno).

We focus on direct state provision. This begs the question of whether the state should provide housing directly or purchase housing on the private market. However, including state purchases from the private market would introduce the local real estate market into the system, change the nature of the problem, and reach beyond the available data. Our analysis is made possible by accessible data on investments in housing made by the state of Washington. We obtained data on three sponsored housing projects that differ in terms of the technology used, capital intensity, and the housing permanence. The projects include permanent (capital intensive) structures (apartments); seasonal housing in converted shipping containers; and emergency tent camps.

In the remainder of this paper we implement an optimizing investment model to analyze this housing demand problem. The model accounts for the seasonal peak demand for migrant housing with both annual variations and seasonal cycles. We apply the model to the three housing options using cost data from the three state projects (year-round, seasonal, and emergency housing). As with the general peak load problem, we assume that all stochastic demand must be met by one of the three alternatives and that these three alternatives include all options. One option is designated the emergency or default outcome. Hence, the three alternatives exhaust the feasible set or dominate any other options. While this assumption is adopted for analytic convenience, we note that it is justifiable on social welfare grounds if the state does not permit "substandard housing" but instead requires that full social cost housing be provided even in the emergency or default case. Finally, we employ data for the entire Washington seasonal farm labor population for convenience, but we do not mean to imply that the state sector should provide all seasonal farm workers' housing. Determination of the "right size" of the state housing sector raises important normative and analytic questions, but they are beyond the scope of the current study.

Literature: Peak Load Pricing and Investment

The peak load problem refers to the issue of determining efficient investment and pricing in markets characterized by economically "non-storable" commodities whose demand varies periodically. The essence of the peak load problem is that the installation of extra capacity to meet peak demand would result in costly underutilization during the off-peak time (Crew, Fernando, and Kleindorfer). The classic example of a peak load commodity is electricity, where production must match demand *at all times* over the course of a variable planning period. Peak load theory was developed to optimize the pricing system and investment schemes in public utilities by applying marginal cost principles. The early literature focused on the demand side, examining welfare-maximizing prices for a simple deterministic peak load model (Boiteaux 1949; Steiner; Williamson). The optimal price in the deterministic demand model is the sum of two parts: the operational costs plus an additional amount to ration demand through the cycle. Subsequent work (Boiteaux 1951; Brown and Johnson) extended the traditional demand model to a risky environment, allowing for a stochastic demand. While Brown and Johnson found results comparable to the riskless model, the inclusion of uncertainty in the model resulted in lower optimal prices at all times and, in general, higher optimal capacity compared to deterministic models. Notably for our study, Brown and Johnson extended the analysis by incorporating the issue of capacity investment level. They recommended that the optimal investment level be selected in such a way that the truncated expectation of the willingness to pay of the marginal disappointed user should be equal to the marginal capacity cost.

Crew and Kleindorfer (1971, 1976, 1978) expanded the analysis by examining simultaneously the effects of stochastic demand, multiple-year planning, and diverse supply technology, including multiple plant types of differing cost characteristics, on the welfare maximizing policy of public enterprises. Further contributions to the literature encompass the cases of storable products, supply side uncertainties, and outage costs.[1] Recently, models of peak load pricing and investment have been applied to a broad set of issues in fields such as telecommunications, transportation, advertising, concerts and games, and storage facilities.

In this paper, we extend peak load investment theory to the case where there are multiple seasons within the planning cycle and where the investment options include technologies that vary in duration (single or multiple seasons) as well as technologies that vary in capital intensity. This extension to multiple time periods complicates the method of finding the optimal solution since the cost of occupancy in off-peak periods will be conditional on the housing built to meet peak period demand.

The aforementioned approach is a net present value investment model. In recent years, many investment studies have incorporated aspects of real options. Dixit and Pindyck and others extended the analytics of financial call options to the domain of real investment problems. The real options model or "new investment theory" emerged because most previous business versions of net present value investment modeling assumed that projects were reversible and that investment could not be delayed. In truth, once built, projects are often "sunk costs" that cannot be reversed or are costly to reverse (for example, machinery is highly specialized). The presence of nonreversibility increases the cost of a bad investment. Also, investment can often be delayed to allow the investor to obtain more information about potential costs and returns. In principle, a proper investment analysis should take into account such alternative timing and reversibility cost issues. (While the real options approach specifically and clearly addresses these issues, Abel et al. note that a more sophisticated NPV investment analysis would include these features.)

Despite the general importance of uncertainty regarding reversibility and investment delay, we do not explicitly apply the real options approach for a number of reasons. These reasons include the lack of appropriate data, problems with specifying the nature of investment delays for an obligate good, possible partial reversibility, and the fact that

[1] For an extended literature review, see Crew et al.

we are treating this as a public rather than private investment case. However, it is important to note that the existence of demand uncertainty increases the cost of investment (the real option value) and hence lowers its relative attractiveness. We comment further in the conclusions using some of the results from sensitivity analysis.

Theoretical Model of Peak Load Pricing and Investment

It is assumed that the goal of state government is the maximization of the expected value of welfare. In the absence of market failure conditions, a standard measure of economic welfare considers the net social benefits to be the sum of total revenue (TR) and (Marshallian) consumer surplus (S) minus production costs (PC).

$$(1) \quad W = TR + S - PC$$

Marginal conditions for a general social welfare maximum can be found by taking derivatives to find first order conditions, which will give the standard results requiring marginal social costs to equal marginal social benefits. The operational model takes demand as given (but stochastic) and assumes that demand must be completely accommodated. Social welfare is maximized by minimizing the costs of satisfying the given demand. In the remainder of this section we present a formal model of the peak load investment model to meet demand, and begin with a brief nontechnical overview of the model.

Demand is divided among n periods with each period having an independent stochastic demand. Costs are evaluated for m alternative housing strategies that range from a high capital cost–low operational cost alternative to a low (zero) capital cost–high operational cost scenario. Costs are assumed to be such that the ranking of alternatives in terms of increasing order of capital costs is inversely related to their ranking in terms of operational costs. (Any other alternatives would be dominated in any case.) In the empirical application of the model, three alternatives are considered over two seasons.

Once capacity is created, the cost of satisfying demand is minimized if the lowest operational cost housing alternative is used first, the next lowest second, and so on (Equation [3]). Total costs are the sum of the fixed capital costs and the varying operational costs. To solve the investment problem, one minimizes long run expected costs.

Formally, for a commodity that faces a stochastic demand, the gross surplus (i.e., $TR + S$) is given by the integral under the inverse demand curve up to the actual amount supplied. Let $x = (x_1, \ldots, x_n)$ be the vector of quantities demanded in period $i = 1, \ldots, n$, and let $p = (p_1, \ldots, p_n)$ denote the corresponding vector of prices. Demand in each period i is assumed to be in the additive form, and can be represented as (we are suppressing notationally other factors that shift the demand curve):

$$(2) \quad D_i(p_i, u_i) = X_i(p_i) + u_i,$$

where $X_i(p_i)$ is the mean continuously differentiable demand in period i. It is assumed that an inverse demand function, P_i exists; and u_i is the random disturbance term where $E(u_i) = 0$, for all i. For simplicity, it is assumed that the relevant planning cycle is divided into n periods of equal length.

Technology is specified as consisting of m types of suppliers, indexed by $\ell = 1, 2, m$. Suppliers have constant marginal (unit) operating costs b_ℓ and marginal (unit) capacity costs β_ℓ. A key assumption is that marginal operating costs b_ℓ and capacity costs β_ℓ are inversely related and can be strictly ranked so that technologies with the highest capacity costs have the lowest operating costs, and so forth:

$$(3) \quad \beta_1 > \beta_2 > \ldots > \beta_m; \qquad 0 < b_1 < b_2 < \ldots < b_m$$

The optimal short-run (operating cost-minimizing) output $q_{l,i}(x_i, q)$ produced by plant ℓ to meet a given market level of demand x_i in period i, given the preceding cost structure and installed capacities q, is then defined by:

$$q_{l,i}(x_i,q) = \min\left\{\left(x_i - \sum_{k=1}^{l-1} q_{k,i}(x_i,q)\right), q_l\right\},$$

(4) $l = 2,\ldots,m$

$$s.t. \qquad x_i \geq \sum_{k=1}^{l-1} q_{k,i}(x_i,q) \qquad \text{for } l \geq 2$$

where $q = (q_1, \ldots, q_m)$ represents the vector of installed capacities of suppliers 1 through m, and output of the first supplier is defined by $q_{1,i}(x_i, q) = \min\{x_i, q_1\}$. The long-run (operating plus capacity) production costs over an n time period planning horizon can then be defined as

$$(5) \qquad PC = \sum_{l=1}^{m}\sum_{i=1}^{n} b_l q_{l,i}(D_i(p_i,u_i),q) + \sum_{l=1}^{m} \beta_l q_l.$$

Let S_i denote the total output from all plants in period i. Then, for any given values of u_i, p_i, and q, the actual output in any period i is given by the minimum of real demand or total installed capacity:

$$(6) \qquad S_i(p_i,u_i,z) = \min\{D_i(p_i,u_i),z\},$$

where $z = \sum_{l=1}^{m} q_l$ represents total capacity of the industry.

Given that supply must always meet demand, welfare maximization is achieved by minimizing the expected value of the total production costs expressed in Equation (5) contingent on all the preceding assumptions. In principle, if demand were to exceed capacity, rationing costs generally occur, requiring the ranking of customers according to their willingness to pay. However, to reflect the reality that all workers must reside at some physical location when not working and given a social value assumption that all workers must have "adequate" housing, we treat the demand for housing slots as a constraint that must be met, albeit the constraint is *stochastic*. In effect, the excess demand is subsumed under the emergency housing alternative (though see brief discussion in Conclusions). Therefore, additional rationing costs are not considered.

Application of the Peak Load Model to Housing Investment

We begin with the basic method developed by Brennan and Lindner, but we extend their procedure in two substantive ways: we divide the planning cycle (usually one year) into a multi-season planning cycle with n seasons, and we add technology with intermediate duration (seasonal versus permanent or year-round housing). In principle, n could be any number of equal-sized seasons, and the model could also be extended to unequal season lengths. The mathematics become increasingly more tedious as time periods are added because the costs of occupation in each period depend on the capital investment made in the most capacity-constrained period.

The demand for housing in a particular area is derived from the total number of farm workers. (The demand can be scaled up or down, for example to include dependents or to incorporate co-occupancy of housing in shifts.) All workers must be housed in some fashion, but the number of workers present at any given time is uncertain. In this application we divide demand for housing into the off-season and the high season (i.e., $n = 2$). The off-season runs from November through April. Housing demand increases substantially during the May–October season as a result of the need for pruning, harvesting, and related activities.

Three types of housing are available. Year-round housing has high fixed costs but low operating costs that are incurred only for the proportion of time it is in use. In the two-season model, year-round housing (if built for the high season) is still available for the off-season, essentially for operating costs only. At the other extreme, dedicated emergency housing (e.g., tents) has relatively trivial (we assume zero) fixed costs, but it incurs very high operating costs when it is occupied.[2] We also include an intermediate technology.

[2] These costs include the setup of entire tent-based communities, together with all of the attendant services required, including such things as utilities, bathing facilities, bathrooms, waste management services, and the like.

Seasonal housing can be used for either one of the two seasons or for both. Seasonal housing refers to semi-permanent housing that can be "mothballed" for some part of the year. Generic examples include summer "cabins by the lake" or mobile homes. In the data relating to our study, seasonal housing comprises converted commercial inter-modal shipping containers.

While seasonal housing is still subject to annual fixed costs, the operating costs are incurred only for the season when it is actually in use. In our application seasonal housing might be used for just one season or for the entire year. In principle, the incremental cost could differ for seasonal housing used for one season or for two seasons. In our empirical results, the seasonal housing is only used for one season.

Let β_Y and β_S indicate the unit capital construction costs for year-round (Y) and seasonal (S) structures, respectively. Let b_Y, b_S, b_E represent the unit operating costs for year-round structures, seasonal structures, and emergency (E) tents, respectively. Finally, let C_Y, and C_S indicate capacities for year-round and seasonal housing. Capacities for dedicated emergency housing are variable and are simply equal to the amount of emergency housing supplied. For simplicity, emergency tents are assumed to be available in any quantity required to house residual worker households not accommodated by the other two housing technologies. It is assumed that the condition in Equation (3) holds, and in addition the total unit costs are greater for seasonal housing than for year-round structures as

$$\beta_S + b_S > \beta_Y + b_Y. \tag{7}$$

Crew and Kleindorfer (1978) point out that, in the case of a stochastic demand, the optimal short-run allocation of demand to capacity is achieved by first using the structures with lowest operating costs. In this study, this implies that year-round housing, once built, should be operated first and followed by an optimal combination of other structures.

The expected value of the total cost function to be minimized for the case of a multi-season (n season) demand and m = 3 technologies can be expressed in general form as follows:

$$\begin{aligned} TC = & \left\{ \beta_Y C_Y + b_Y \sum_{i=1}^{n} E[x_i(C_Y)] \right\} \\ & + \left\{ \beta_S C_S + b_S \sum_{i=1}^{n} E[x_i(C_S)|x_i(C_S) > C_Y] \right\} \\ & + b_E \sum_{i=1}^{n} E[x_i - C_Y - C_S | x_i > C_Y + C_S]. \end{aligned} \tag{8}$$

The first parenthetical expression of Equation (8) represents the expected total costs of operating year-round (type Y) housing for both seasons as the sum of capital costs $\beta_Y C_Y$ and the expected utilization costs incurred when year-round housing is occupied. Terms in the second parenthetical expression of Equation (8) represent the expected total cost of operating seasonal housing (type S), again as the sum of capital costs $\beta_S C_S$ and the expected utilization costs for seasonal housing, the latter being driven by demand that exceeds the carrying capacity of permanent housing, which motivates the *conditional* expectation used here. In this formulation, the term $\beta_S C_S$ is the annualized cost for seasonal housing adjusted for any differences in capital costs between single and multiple season operations. As there are no capital costs for emergency housing (type E), the last term indicates only the expected operating costs of emergency housing. It is driven by the amount of housing needed that exceeds the sum of permanent and seasonal housing capacity.

Taking the derivative of the total cost function with respect to capacities C_Y, C_S and solving the first order conditions, the efficient rules of investment are obtained as[3]

$$1 - \sum_{i=1}^{n} \Phi_i(C_Y) = (\beta_Y - \beta_S)/(b_S - b_Y) \tag{9}$$

$$1 - \sum_{i=1}^{n} \Phi_i(C_Y + C_S) = \beta_S/(b_E - b_S) \tag{10}$$

[3] Derivation of the first order conditions is available from the authors. For purposes of deriving explicit rules of investment, a normal distribution is assumed for the cumulative distribution of the variable.

where Φ (•) is the cumulative distribution function (CDF) of the number of farm workers during period i. The implications for investment choice based on the conditions shown in Equations (9) and (10) are that the state should invest in year-round housing as long as the expected cost of using year-round housing equals the expected cost of using seasonal housing (the marginal expected cost of investment in year-round housing does not exceed the marginal expected benefit derived from this investment). This is satisfied for the level of investment in housing capacity of type one, C_Y, that satisfies the condition in Equation (9). Beyond level C_Y, investment should proceed in seasonal housing up to the point where the expected cost of investment is just equal to the expected cost of supply failure (housing type three—emergency housing). This is achieved by investing in housing capacity of type two (seasonal housing) at level C_S, which satisfies the condition in Equation (10).

Data

Data for this study were collected from three state funded projects. Data from the San Isidoro Project located in Granger, WA represents year-round housing. Twenty-six housing units make up the project with a total occupancy up to 180 persons. The Diocese of Yakima Housing Services provided the data. The Diocese developed and manages the housing complex.

The Esperanza project is a community-based project located in the area of Mattawa, WA. It represents a seasonally occupied housing project that is available to farm workers for six months out of the year. Migrant workers who are employed by local growers use this complex. Esperanza has 40 units with a total of 240 beds. It is open to both families and singles. Each unit consists of a 40-foot cargo container transformed into a 320-square foot housing unit. Grant County Housing Authority provided capital construction costs and operating costs for the Esperanza project.

The Pangborn tent-camp located in Wenatchee provides temporary shelter to migrant farm workers during the cherry harvest. The basic concept was developed to house large numbers of farm workers engaged in short-term harvest activities. Usually, the camp is operated for about three weeks on a site. The camp is then torn down and moved to another site to make the best use of camp resources. The camp has 50 tents and its total occupancy is 300 people per site. North Columbia Community Action Council and the Office of Community Development in Washington provided the data.

Capital costs for the projects analyzed here are annually recurring nonuse related (fixed) costs. They include construction and land costs. Operating costs are defined as use-related (variable) costs and are borne only if the housing unit is being used. Labor costs (management, maintenance and administration wages and benefits) are the bulk expense of the operating costs. Other items include water, electricity, sewer and garbage, and maintenance costs. Capital and operating costs for the projects are given in Tables 2 and 3 and additional explanations on cost calculations are reported in Appendix A.

Marginal capital and operating costs of the two first projects are inversely related as described in Appendix A, with year-round housing as capital-intensive structures and seasonally occupied units as more operational cost-intensive. Capital costs for San Isidoro and Esperanza were amortized to obtain a constant annual cost that is equivalent to a present value cost.[4] The interest rate used for the base case is 5%, with sensitivity analysis reported for some variations. Note that, in the theoretical model, the seasonal housing would have different capital costs depending on whether it was used for one or two seasons in a year. We simplified the empirical calcu-

[4] The investment problem can be approached in terms of either the present value of all costs over time or as amortized annual costs. Although solutions to investment problems will be affected by assumptions about final values and reinvestment, we suppress these issues as a diversion from the main topic.

Table 2. Construction and Operating Costs for Year-Round, Seasonal, and Emergency Housing in Washington State

Project	Capital Construction Cost ($)	Annual Operating Cost/Unit ($)	Occupancy Worker/unit	Life (Years)
San Isidoro (Y)	89,715.00	1,640.00	7	50
Esperanza (S)	27,279.00	2,114.00	6	25
Pangborn Camp (E)	–	9,254.45	6	–

Table 3. Marginal Costs of Investment in Year-Round, Seasonal, and Emergency Housing in Washington State

Housing Type	Marginal Capital Costs ($/person/year)	Marginal Operating Costs ($/person/year)	Total Marginal Cost ($/person/year)
Year-round	27.29	234.28	261.57
Seasonal	8.07	352.33	360.40
Emergency	0	1,542.00	1,542.00

lations by assuming the same rate of depreciation whether the seasonal housing was used for one or two seasons.[5] The operating costs for the Esperanza project were calculated based on a six months-per-year period (one season). It is assumed that operating costs are constant and would double if the facility were operated for two seasons. This allows comparison of marginal operating costs between projects on an annual basis.

The tent camp is the emergency solution for demand. It is the default or residual solution—meeting all demand not met by the two main alternatives. All costs are treated as variable costs. The cost per person for the emergency housing was calculated by subtracting the cost of the reusable items from the total costs and assuming full occupancy of the camp. The tents have substantially higher operating costs than the other two housing options.

Estimates of the marginal costs of the three types of housing are given in Table 3. Note that the long-term costs for the more permanent structures should include some depreciation and repair costs. We have included estimates from the project operators to cover ordinary repair costs, but the true long-term cost is unknown. We note the obvious: while the state may find tents to be the least cost emergency housing, from the perspective of the worker or the employer, lower cost alternatives clearly exist (old cars, undeveloped campgrounds).

[5] This simplification has no effect on our results because seasonal housing is only used in one season in all our solutions.

Investment Analysis and Results

The solution of marginal efficiency conditions shown in Equations (9) and (10) indicate that year-round housing is the most efficient option and should be used to meet demand 84% of the time. Beyond that, investment in seasonal housing should follow about 16% of the time. Tent camps are an expensive alternative and are used to satisfy only extremes in demand—a tiny 0.01% of the time. In effect, the solution comprises almost wholly a combination of permanent and seasonal housing and emergency housing is used in only extraordinarily rare circumstances.

While the equations are solved mathematically, a figure can provide intuition about the process. Based on the marginal efficiency conditions shown in Equations (9) and (10), we can construct a cost-based efficiency

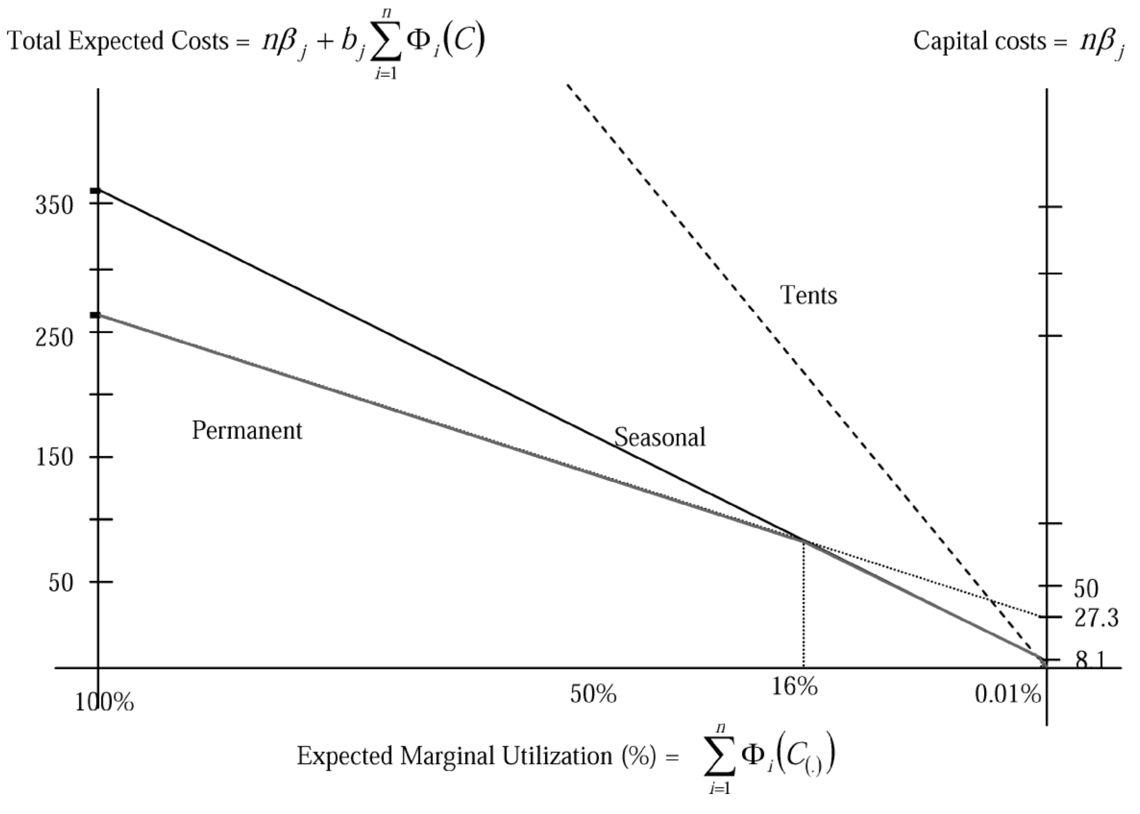

Figure 1. Efficiency Frontier of the Optimal Combinations of Technology in Farm Worker Housing
Note: Vertical axis = expected costs; horizontal axis = increasing capacity and decreasing marginal utilization, left to right

frontier. Figure 1 depicts only the peak period since the peak period defines capital construction. The second period is conditional on the first period, so it cannot be drawn *ex ante*.

The horizontal axis of the diagram indicates the expected marginal utilization of the total housing capacity as the amount of capacity built increases. The vertical axis represents the *expected* total marginal costs of investing in farm workers housing:

$$(11) \qquad \left(\beta_j + b_j \sum_{i=1}^{n} \Phi_i(C_{(.)})\right)$$

where n denotes the number of periods that demand is divided into, and β_j and b_j indicate the unit capital cost and period operating costs for the j type of housing.

The three straight lines represent the sum of the unit capital costs and the marginal operating costs for each of the three alternatives at given levels of predicted occupancy. The intercept along the right vertical axis for each alternative indicates costs for housing that is built, but unoccupied (i.e., only capital costs are incurred). The intercept on the far left shows costs when the unit is 100% occupied—incurring both annual unit capital costs and full marginal operating costs. A straight line connecting the two reflects the operating costs, and its slope is the (constant) marginal operating cost. The marginal unit has operating costs proportional to its probability of occupancy. Thus, where the marginal unit is occupied 50% of the time, it incurs half of the period's operating costs.

The lower, jointed envelope of the three lines is the efficiency frontier. The most efficient (least cost) investment is found by choosing the mix of investments consistent with the level of occupancy that must be met.

Table 4. Estimated Optimal Levels of Investment in Farm Worker Housing for State of Washington by Number of Hired Farm Workers, 2000–2005

Regions	Coefficient of Variation Off and Primary Season Demand	Level of Investment Year-Round Housing (persons)	Level of Investment Seasonal Housing (persons)
State	0.32; 0.26	56,753	17,905

For example, if the investment goal were to provide for occupancy 50% of the time, one would build all permanent structures at a marginal per worker cost shown by the lowest line.

From this diagram one can see that, where demand is certain and the level of investment is low, year-round structures are an efficient option (left side of graph) since expected costs are lower than the seasonal and emergency alternatives. However, as the probability of housing utilization falls, investment in seasonal structures becomes cheaper. Note that the seasonal slope decreases faster than the slope of the year-round structures—($b_S > b_Y$). As the extreme right is approached, the expected marginal utilization becomes extremely low, and use of the tent camps becomes the best alternative. The kinks in the efficiency frontier are switchover points where cost is equivalent for two technologies, as described in the marginal utilization conditions of Equations (9) and (10).

Marginal operation costs in the off-peak period are conditional on the construction of facilities built according to the pattern shown in the peak period. Recall that permanent facilities are built to accommodate 84% of the peak period and seasonal (intermediate) capacity is built to accommodate most of the remaining 16% of full peak load. This means that in the primary solution, whatever permanent housing is built in the peak season is available to house workers during the off season. For this solution, the probability of needing the emergency housing in the off season is essentially nil.

Optimal Levels of Investment and Sensitivity Analysis

Optimal (least-cost) levels of investment for the state of Washington were calculated based on the historical distributions of the number of farm workers for the years 2000–2005. Marginal efficiency conditions were solved to derive optimal investment capacity by type of structure using the nonlinear equation solving software in the SAS package. Calculated minimum cost capacity levels are reported in Table 4.

In order to meet demand at the state level, results show that investment in year-round permanent housing should be sufficient to house 57 thousand people, which will house all workers 84% of the time. This compares to a mean demand for 45,000 in the high season. Investment in seasonal housing is for around 18,000 "slots" or people.

To consider a more risky environment, sensitivity to increase in variance can be examined. Results are shown in Table 5.

In this table, optimal levels of investment in year-round structures for the state are derived assuming different levels of variability. Increasing variability expands uncertainty and pushes out the tale of the distribution. As a result, the total required housing level increases. An increase in the coefficient of variation from 0.3 to 0.6 induces an increase of about 23% in the least cost investment in year round housing. As one would expect, it increases the cost-efficient level of seasonal housing by a much larger amount—doubling the amount of seasonal housing and increasing the seasonal housing as a proportion of permanent housing from 30% to 60%.

Because we lack data on other housing alternatives, we cannot be certain how representative these project costs are. This suggests exploring wider confidence intervals through sensitivity analysis. Moreover, costs may change over time due to changes in technology and construction input prices. Data from

Table 5. The Effect of Uncertainty on the Level of Optimal Investment for Year-Round and Seasonal Housing for the State of Washington

Coefficient of Variation[a] During Off and Primary Season Demand[b]	Optimal Investment (year-round) (persons)	Optimal Investment (seasonal) (persons)
0.6	71,808	40,260
0.5	67,368	33,550
0.4	62,928	26,840
0.3	58,488	20,130

[a] The Coefficient of Variation (CV) is assumed equal for both the base and the season demand.
[b] Mean level for the base demand is 14,446 and mean level for high season is 45,168.

Table 6 demonstrate that the optimal mix is sensitive to cost assumptions—different optimal levels of investment are obtained as cost assumptions change.

Table 6 shows that an increase of 25% in operating costs or a decrease in capital costs of 25% would favor an increase in the ratio of the year-round structures of up to 87% to 88% (cases 2 and 5). This change would be accompanied by an increase of 3% to 4% in total investment costs. The opposite outcome would occur with a decrease in the operating cost or an increase in the capital costs (3 and 4). In these cases a shift of the expected marginal utilization towards the left of CDF causes a decrease in the optimal levels of investment. Similarly, a decrease of 50% in tent costs will cause a substitution away from the seasonal structures in favor of the tents but will not affect use of permanent structures (row 6). While the increase in tents is large relative to the baseline number, the number of tents is so few that the overall pattern hardly changes.

Several scenarios may generate the need for different overall levels of housing slots. For instance, proportionate changes in the total number of required *housing slots per worker* will change the results for both cost and investment configuration. The need to house farm workers' dependents would increase the total required housing slots (and housing cost) per worker, whereas sharing beds by farm workers ("hot beds") reduces the number of slots required per worker (reduces costs). Hence, if some workers have dependents

Table 6. Sensitivity Analysis of the Effect of Alternative Cost Assumptions on the Optimal Level and Mix of Housing[a]

Cost Assumptions	Optimal Investment (Year-Round) (Seasonal)	Optimal Mix of Investment (%)	Change in Optimal Level (%)
Base case level	56,753.7	(84):(15.99):(0.01)	0
	17,905.7		0
Operating costs increase 25%	58,430.2	(87):12.9):(0.01)	+2.95
	17,148.6		−4.22
Operating costs decrease 25%	54,386.1	(78):(21.99):(0.01)	−4.17
	19,052.6		+6.40
Capital costs increase 25%	54,940.6	(80):(19.99):(0.01)	−3.19
	18,775.6		+4.86
Capital costs decrease 25%	58,893.3	(88):(11.99):(0.01)	+3.77
	16,947.2		−5.35
Tent costs decrease 50%	56,753.7	(84):(14.99):(0.02)	0
	13,980.2		−21.92

Notes: Number of year-round and seasonal units, respectively. Ratio of units of year-round to seasonal to emergency units.
[a] Mean and CV are the historical levels for the state for 2000–2005 data.

Table 7. Sensitivity of Optimal Investment in Year-Round Housing to Changes in the Discount Rate[a]

Year-Round Housing	Discount Rate (%)	Change in Capital Costs/Person (%)	Optimal Investment (Persons)	Change in Optimal Level of Investment (%)
	3	−29	59,699	+5.19
Base case	5	0	56,753	0
	8	49	40,742	−6.73

[a] Mean and CV are the historical levels for the state for years 2000–2005.

requiring housing, so that the cost of housing each worker goes up, the investment ratio would change in favor of seasonal structures and the cost of investment would increase by up to 5%. Essentially the opposite results emerge if workers occupied fewer slots per worker by sharing beds.[6] The later result also applies for reduced participation by the state sector.

Effects of different discount rates on the capital costs for year-round housing are given in Table 7. Reducing the discount rate to 3% (from 5%) has an effect similar to that of an increase in the operating costs as illustrated by the data in Table 7.

Reducing the interest rate also lowers the capital costs of the structures and moves the expected marginal utilization higher resulting in an increase in the level of optimal investment in year-round structures. The opposite impacts occur for a higher discount rate of 8%. This is expected since the increase in interest rate raises the capital costs and vice versa.

Discussion and Policy Implications

Based on our data and methods, results of this study suggest that investment in year-round housing should be used to meet most of the demand for seasonal housing. The base scenario implied permanent housing for about 84% of the (stochastic) demand and seasonal housing for most of the rest. Investment in emergency housing (tents) is inconsequential; it would be used very rarely (about 0.01%) amount of peak demand. These results are fairly robust. Sensitivity analysis shows a fairly stable pattern with relatively small changes in the investment pattern induced by relatively large changes in costs, variance, and interest rates.

Results favoring permanent structures seem counterintuitive. They raise the reasonable question: why invest a substantial amount of money in providing an apparently expensive infrastructure for an almost invisible, clearly impermanent, and socially marginalized labor force? The short answer is simply that it is the cheapest option given the assumptions adopted here. More broadly, this question stimulates the following discussion.

One driver of results is the explicit assumption that housing is a necessity—a literal necessity in that everyone must be "housed" somewhere. It follows that the supply of "housing" must equal demand. The seasonal housing problem is analytically identical to a peak load storage problem—full "storage capacity" must satisfy a highly variable demand.

The location and nature of the "storage" place is, however, much more complicated than storing electricity, water, or grain. The housing market is complex, partly because it includes several stakeholders, each of which may have a different vision of the "demand" for housing. Starting with the seasonal farm workers, we assume they desire an inexpensive and safe place to live. Location matters to

[6] In some migrant worker situations, workers with differences in "shifts" sleep at different times (hot beds). Thus, six workers might be housed in a space designed to accommodate four. This situation would lower investment costs along the lines discussed previously. In the Washington case, this scenario is plausible for some workers in the processing sector but unlikely for field workers.

them for access to work, health and education services, food, and entertainment. However, most seasonal *field* workers are migrants who hope to send large remittances home. Moreover, many are insecure because they are undocumented. Therefore, workers will view housing as a short-term consumption necessity, not an investment problem.

Farmers may care more about worker housing than many employers because housing can be a part of the compensation package that attracts workers. In industries employing workers located far from their employees' homes (e.g., destination tourism/recreation and mineral exploitation), employers sometimes provide housing as part of the job contract. Often such industries have isolated sites owned by a single entity. Since farming is more atomistic, one must look at individual farmer incentives. While farmers may be collectively interested in providing housing, individual incentives work against providing housing because most seasonal laborers work on more than one farm. The housing provided by Farmer A could be a favorable externality for the neighboring farmers. Indeed, informal remarks by farmers to the researchers indicated that they only provide housing to their core employees.

Local communities have an interest in seasonal labor housing since migrants often comprise a big population influx in relatively rural areas. Local communities will want to minimize negative externalities created by low income housing. They will also want to efficiently use their local community infrastructure (education, health services) for the services that will be used by these workers.

The key point is that, while each stakeholder would like to "store" migrants, their detailed motivations are nuanced. Each stakeholder has a different demand and a different definition of costs for housing the same worker. Given the multiple demands, it is almost inevitable that there will be public interest in seasonal farm worker housing. The state has an interest that represents stakeholders *individually and collectively*. State involvement raises both normative/ethical welfare economics issues and an applied public choice/political economy issues (see discussion that follows). One can presume that the state has a relatively high demand for "quality" housing, where quality refers to safety and resident well-being. We can presume that higher quality is more expensive than lower quality. Hence we believe that housing provided by other stakeholders would differ significantly in quality and cost from the case we examine.

In summary, our results are based on three conditions: 1) the primary perspective taken is that of the state, 2) the state demands relatively high quality housing, and 3) the housing accounting identity requires the housing of all workers. Given these conditions, a solution emphasizing permanent housing is less surprising.

While our study is a simplification of the actual housing market and specifically ignores the contributions of the other sectors, the current approach and results have provided some of the groundwork for a more complete analysis. Specifically, our approach could be used to model the least cost investment strategy for a representative agent for each stakeholder. In addition to more data, additional work would be needed to develop a normative and/or predictive model for each agent's preference function (individualistic or collective) and to estimate the interactions in a real world case.

Beyond the implicit restrictions, there are a number of cautions against generalizing the results of this study. First, we note that our study is based on the specific financial data from just three public housing projects and we do not have information to know how robust these cost data are. Another matter is that housing is geographically fixed. Housing markets are tied ultimately to locations, and we have not modeled these spatial dimensions. Thus, the mobility of tents may make them a better choice when geography is included.

A major potential qualification to our results concerns the timing of investment. As we noted earlier, much current investment literature uses the real options (or new investment approach) to address the issue of efficient investment timing under uncertainty.

We did not use this approach, partly from insufficient data, and more directly from lack of a sufficient framework for this specific investment problem. The real options literature is focused mainly on the timing of investment and disinvestment. Where demand is given, the alternatives are to invest to meet demand, or failing to do so, to retreat to the default. In our case, the default was emergency tents. So, in one respect, our specification already contains a real options approach—where the cost of failing to invest is use of the emergency tents. The study indicates that failure to invest immediately and to rely on the default emergency tents is *prima fascia* inefficient from the public point of view. Sensitivity analysis showed that the investment pattern would hold for large variations in costs of emergency/default housing.

While we were able to directly incorporate demand uncertainty for the public sector, we did not have good information for uncertainty regarding the structure of the labor market. Clearly, the current market structure is subject to uncertain changes from at least two directions—technology and policy. This structural uncertainty means that, in principle, a real options approach is warranted. The possibility of investment delay and the irreversibility of asset disposal (a sunk cost) should be taken into account. However, technological and policy uncertainty would be problematic to model because the probabilities are simply unknown. Our sensitivity analysis does show that, as one increases the variance, more seasonal and fewer permanent structures should be built. Hence, the sensitivity results suggest that one may wish to bend the results towards fewer permanent structures in recognition of general uncertainty.

While deeper modeling of the policy–technology labor market future is beyond the scope of the present paper, some simple results can be found by hypothesizing likely scenarios. The general direction of technological change in agriculture is towards substitution of capital for labor, so analysis of different labor demand scenarios would be useful. Our model results can be used to predict the need for housing under different scenarios by proportionate increases in the mean number of required "slots." That is, total investment would be increased or decreased but the configuration of housing (permanent, seasonal, emergency) would remain as calculated here—if there are no changes in the probability structure of demand.

Turning to policy uncertainty, one can distinguish at least four new policy scenarios: 1) enhanced guest worker programs, 2) legal residency programs for currently undocumented workers residents, sometimes labeled "amnesty programs," 3) increased restriction on illegal immigration or 4) no change in policy. Recent congressional debates focused on a package including all three of the policy change alternatives. In the end, the status quo prevailed. No major legislation has been passed at the time of this writing, but some combination of these measures may be enacted in the future.

Impacts of policy changes on housing demand and, hence, investment requirements are speculative. Enlarging the currently limited guest worker program would institutionalize and legitimize many currently undocumented seasonal workers. One imagines that this might increase the expected wages and stability of the guest workers. Guest workers tend to be paid more than illegal workers, so we expect the net effect to be higher wages for a more stable labor supply. Guest worker programs also clarify the time interval required for housing. For the farm worker element of housing demand, the key question would be how much of their income workers would spend on housing investments in Washington versus remittances.

A residency or amnesty program would likely have little effect on the need to house seasonal farm field workers. Farm field work tends to occupy the bottom rung on the employment ladder. Workers who could acquire legal residency would be unlikely to stay in field work but would move "up the ladder" to construction, for example. It is likely that field worker slots would be filled by new immigrants (legal or illegal) just as now. While speculative, this appears to be what occurred during the last episode of "amnesty."

Increasing enforcement intensity has the effect of making seasonal labor more expensive by increasing the risk to illegal immigrants and (depending on the law and its implementation) to employers. One possible consequence is a reduction in numbers of illegal seasonal migrants replaced by either legal residents or guest workers, presumably at higher wages. (See previous discussion of guest workers.) If increased wages attract legal workers to replace a reduced supply of illegal seasonal workers, the impact on housing depends on whether the replacement workers are internal U.S. migrants (California, Texas) or local laborers. To the extent workers are from the local labor force, housing needs will logically decline. If U.S. migrants supply the markets, the housing problem will be mostly unchanged.

Finally, suppose that more permanent housing is indeed efficient. Then, one may ask why there isn't more state provision of housing for seasonal agricultural workers? At least three reasons surface. First, while we did not use a real options model, a general rule that emerges from real options models is that more uncertainty often increases the cost and postpones the implementation of investment plans. Given the policy and technology uncertainties above, perhaps state agencies are waiting for more information to emerge regarding the need for housing before they commit their funds. Interestingly, our analysis suggests that the state sector is currently "over-investing" in tent housing since our model suggests that almost any nonzero investment in tents is "too" much. Perhaps state-supported tent camps reflect the uncertain investment and political climate for state investment.

A second reason why states may not be investing in permanent housing is that they have more accurate and conflicting investment data. Thus, the results would mover towards seasonal or temporary housing if the relative prices of permanent and seasonal housing are higher than our data show or the private and social costs of temporary housing were relatively lower than our data.

A third and final explanation for the relatively low level of public investment in migrant housing concerns the political economy of state governments with limited budgets. Allocation of funds from limited state budgets weighs investment by social values that transcend the goal of efficiency alone. Housing for seasonal farm workers may simply not be ranked highly enough relative to a scarce budget and the consideration of more inclusive social criteria.

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Appendix A

COST CALCULATIONS

To allow comparisons of the data between the three projects, calculations are reported on an annual basis. Marginal costs are assumed to be constant.

ESPERANZA PROJECT (SEASONAL)

The Esperanza project operates six months out of the year. It has 40 units and each unit houses six people (total 240). The life expectancy of the structure is 25 years. Capital construction costs reported by the Housing Authority are \$27,279, and operating costs (per season) per unit are \$1,057.

MARGINAL CAPITAL COSTS (MCC)

Capital costs were amortized to obtain a constant annual cost that is equivalent to a present value cost. An amortization factor was calculated for the Esperanza project:

$$AF = \left(1-(1+r)^{-t}\right)\Big/ r = \frac{\left(1-(1+0.05)^{-25}\right)}{0.05} = 14.09,$$

where r denotes the relevant interest rate and t indicates the lifespan of the structures.

Applying the amortization factor to capital costs produces

$$MCC = \frac{\$27,279}{14.09} = \$1,636.$$

Then the amortized marginal capital cost per worker is

$$MCC/Wor\,\text{ker} = \frac{\$1,636}{240} = \$8.067.$$

MARGINAL OPERATING COSTS (MOC)

If the structure is operated for two consecutive seasons, the annual operating costs per unit are

$$MOC/Unit/Year = \$1,057 * 2 = \$2,114.$$

And on a per worker basis:

$$MOC/Worker/Year = \$2,114/6 = \$352.33.$$

SAN ISIDORO PROJECT (PERMANENT)

The San Isidoro project includes 26 units with a life expectancy of 50 years. Total number of occupants is 180 with an average number of seven people per unit. Reported capital construction costs equal \$89,715 and operating costs per unit are \$2,343.

MARGINAL CAPITAL COSTS (MCC)

The present value of an annuity for this project was calculated as:

$$AF = \frac{(1-(1+0.05)^{-50})}{0.05} = 18.26.$$

Capital costs are amortized to obtain a present value cost:

$$MCC = \frac{\$89{,}715}{18.26} = \$4{,}913.$$

And the amortized marginal capital cost per worker is:

$$MCC/Worker = \frac{\$4{,}913}{180} = \$27.29.$$

MARGINAL OPERATING COSTS (MOC)

Assuming 70% occupancy during the year (an assumption backed up by real operational data), the annual operating costs per unit are

$$MOC/Unit/Year = \$2{,}343 * 0.7 = \$1{,}640.$$

And on a per-worker basis:

$$MOC/Worker/Year = \$1{,}640/7 = \$234.28.$$

PANGBORN TENT CAMP (EMERGENCY)

There are no capital construction costs for tents. The only costs that are borne are the operating costs that include the cost of predevelopment and development of the site, plus the use-related costs. These total operating costs for a year (or operating costs for two sites) are calculated at $925,445. There are 50 tents operated during one season with a maximum capacity of 300 people. So, during two seasons, the maximum number of people housed in the camps is 600 and the operating costs per worker are

$$MOC/Worker/Year = \$925{,}445/300 = \$1{,}542.$$