A Use of the Gravity Model to Estimate the Residential Distribution of New Workers at a Large Nuclear Energy Center[†]

Caryl R. Ersenkal and B. L. Dillman*

INTRODUCTION

A nuclear energy center in South Carolina consisting of twelve 1,200 megawatt nuclear plants at a single location is currently the subject of environmental and socioeconomic analyses. The development impact of such a center can be expected to be substantial because of the very magnitude of the project, quite apart from the real or imagined risks to health and safety. An essential element of this analysis involves projection of the location of in-migrants prior to the actual plant construction, as the size of the construction force is expected to be too large for communities to absorb without severe strain on the schools and other public services they provide and on such private markets as that for housing.

In order to accurately assess the impact of a very large infusion of economic activity on levels of employment and income, it is necessary to determine the extent of the area from which the work force will be drawn. This paper involves one aspect of a larger study of total socio-economic impacts. It attempts to develop a model to determine the subareas from which the construction work force will be drawn and the areas in which new construction workers will locate.

THE GRAVITY MODEL

In-migrants to an area will consider two major factors in choosing a particular area in which to live. It is expected that a worker will tend to locate so as to minimize transportation cost, and at the same time, will be attracted to areas offering a wide range of public and private goods. Gravity models account for both of these variables by relating distance (a proxy for transportation cost) and population (an indicator of goods availability) to interactions between areas.

*The authors are, respectively, Graduate Research Assistant and Professor, Department of Agricultural Economics and Rural Sociology, Clemson University.

†Published with the approval of the Director of the S. C. Experiment Station, Clemson University, Clemson, S. C., as Technical Contribution No. 1831.

Gravity models have been employed previously in economic-demographic models to allocate project in-movers associated with the construction of power plants. Several have been based on surveys of worker commuting data in sparsely populated western areas (5) (8) (9) (13). Other work includes that carried out for Oak Ridge National Laboratory (1) and reports by the Wizard Development Group (14).

The gravity model was originally formulated in terms of Newtonian physics and later generalized to model such human interactions as transportation, migration and market sales area identification (3) (7) (11). The basic gravity model states that interaction between two bodies varies directly with a function of their masses and inversely with some function of the distance between them

$$I_{ij} = G \frac{(P_i P_j)}{d_{ij}^b}$$

where: I_{ij} = interaction between center i and center j;

P_i = population at center i;

P_j = population at center j;

d_{ij} = distance between center i and center j;

G = constant to be empirically determined; and

b = exponent on distance.

Many modifications of the basic gravity model are possible. For this study, a formulation which shows the population potential of the plant site j contributed by various subareas i was selected.

$$Wkrs_i = G \frac{Pop_i^{\beta_1}}{Dist_{ij}^{\beta_2}}$$

where: $Wkrs_i$ = number of workers living in area i;

Pop_i = population in area i;

$Dist_{ij}$ = distance from area i to site j;

β_1 = population elasticity to be estimated;

β_2 = distance elasticity to be estimated.

Parameters were estimated by transforming the equation into log form:

$$\log Wkrs = \alpha + \beta_1 \log (Pop_i) - \beta_2 \log (Dist_{ij})$$

where: $\alpha = \log G$

It is expected that the elasticity measures β_1 and β_2 will differ for the two types of workers under study, in-migrants or movers to the site, and non-movers or current residents.

In distributing a given number of workers, TOTAL, throughout a second region B, the parameters α , β_1 , and β_2 are applied to data concerning population and distance for subareas of B. To develop an estimate of workers from each subarea i in B,

$${}_B\text{Wkrs}'_i = \alpha + \beta_1 \log ({}_B\text{Pop}_i) + \beta_2 \log ({}_B\text{Dist}_{ij}).$$

To insure that the total workers allocated throughout B is equal to TOTAL, the estimate of ${}_B\text{Wkrs}'_i$ is normalized such that,

$$A_i = \frac{{}_B\text{Wkrs}'_i}{\sum_{i=1}^n {}_B\text{Wkrs}'_i}$$

where A_i represents the proportion of workers allocated to area i . The actual number of workers distributed to each i is

$${}_B\text{Wkrs}_i = (A_i)(\text{TOTAL})$$

A very comprehensive review of literature on the gravity model has been compiled by Hua and Porell (6). The reader desiring more detailed explanations is referred to this work.

THE DATA

The data utilized in this study were gathered by Duke Power Company by means of a construction worker survey at the Catawba Plant in York County, S. C. (12). The survey included information on place of residence, family size, distance traveled to work, and whether the worker had relocated when he was employed at the Catawba plant. The data were then aggregated by zip code of residence and classified by movers and non-movers.

The data in such a form are especially useful since they provide a basis upon which to estimate the spatial distribution of workers at similar types of construction sites. Since the data were available by zip code, they could be matched to specific towns, county census divisions (CCDs) and counties, and thus related to the Census of Population data available for such areas. Certain discrepancies were identified when commuting distance reported by workers were compared with the distances later estimated by engineers, and observations were eliminated when these differences were greater than 30%.

After aggregating from the zip code level to the CCD and county level, a weighted average of distances traveled by all workers from each such area was

TABLE 1
Gravity Model Applied to In-Movers^a and Non-Movers^b for Two Types of Subareas.

Equation No.	N		α	β_1	β_2	R ²	CV ^c
<i>Zip code areas</i>							
(1)	20	log (In-movers) =	5.79 + (6.82)*†	.289 log (Pop) + (4.00)*	- 1.95 log (Dist) (- 11.20)*	.88	30.3
(2)	24	log (Non-movers) =	5.37 + (5.2)*	.215 log (Pop) (2.51)*	- 1.29 log (Dist) (- 6.18)*	.67	22.6
<i>County Census Divisions</i>							
(3)	23	log (In-movers) =	4.72 + (4.07)*	.412 log (Pop) (3.58)*	- 2.05 log (Dist) (- 11.22)*	.86	33.0
(4)	28	log (Non-movers) =	4.66 + (3.22)*	.254 log (Pop) (1.83)*	- 1.25 log (Dist) (- 5.53)*	.56	26.0

^aIn-movers are defined to be employees that have moved their place of residence in order to work at the construction site.

^bNon-movers are construction workers from the region that did not move to work at the site but commute from their place of residence prior to their construction job.

^cCoefficient of variation

*Parameters are significant to the .95 level.

†Numbers in parentheses are values of Students' t.

utilized as the commuting distance. Furthermore, CCDs and counties attracting fewer than six workers were excluded from the analysis because impact in such areas would be minimal.

ANALYSES AND RESULTS

Commuter patterns for non-mover and mover construction workers at the Catawba Plant were analyzed using the Duke Power Co. survey data. Table 1 presents the results of this analysis for both the zip code areas and for CCDs.

In each set of equations, a better fit, using this simple gravity model, was obtained for in-movers to the study area, than for non-movers. Both the absolute value of the distance and the population parameters are greater for in-movers than for non-movers. The higher distance elasticity indicates that new in-migrants are less willing to commute long distances than are current residents. This is expected since residents have social and economic ties to their current place of residence and would not be expected to move to the work site. In a similar manner, the higher population parameter in the in-mover equations indicates that they are more strongly affected by population size when making a residential decision, presumably because they are concerned with the increased availability of goods and services which a larger population represents.

Considerably less variation is explained when the model is applied to non-movers, indicating that population and distance alone do not fully explain the distribution of non-movers. Other less readily quantifiable economic and social factors and events, some of which may be long forgotten, can be expected to play a more substantial role describing the spatial arrangement of non-movers.

The basic model was modified in several ways in an attempt to better explain this distribution. Various weights were applied to the population variable representing in and out of state locations. Dummy variables were created also to represent critical levels of population. The model presented above, however, consistently provided the best fit with least variation.

The absence of any significant loss in accuracy and the similarity of parameter estimates in the zip code area model and the CCD model indicates that CCD level model is realistic and can be applied with no substantial loss in prediction ability. This is advantageous because of the general availability of data at the CCD level.

APPLICATION TO ANDERSON COUNTY

In order to distribute the estimated number of workers at the proposed Anderson County Nuclear Energy Center, the models developed for in-movers and non-movers using Catawba Plant data were applied using the procedure outlined earlier. It has been projected that 5,900 construction workers will be employed at the NEC in 1989, the peak year of construction (4). Sixty-five

TABLE 2
Gravity Model Allocation of In-movers and Non-movers
to CCDs in the Anderson NEC Region

OBS	CCD	CCD Number	County	Distance	IN ^A _i	NON ^A _i	In-Movers	Non-Movers
1	Anderson	1	Anderson	12.8	0.0547	0.0365	113	140
2	Anderson North	2	Anderson	17.2	0.0187	0.0189	39	73
3	Anderson South	3	Anderson	8.9	0.0940	0.0508	194	195
4	Belton	4	Anderson	19.8	0.0112	0.0138	23	53
5	Belton East	5	Anderson	22.2	0.0043	0.0076	9	29
6	Belton West	6	Anderson	17.6	0.0132	0.0153	27	59
7	Brushy Creek	7	Anderson	28.2	0.0055	0.0090	11	35
8	Fork	8	Anderson	13.3	0.0160	0.0171	33	66
9	Honea Path	9	Anderson	22.6	0.0095	0.0126	20	48
10	Iva	10	Anderson	7.3	0.0822	0.0666	170	179
11	Pelzer	11	Anderson	26.0	0.0058	0.0093	12	36
12	Pendleton East	12	Anderson	19.8	0.0105	0.0133	22	51
13	Pendleton West	13	Anderson	19.6	0.0103	0.0131	21	50
14	Starr	14	Anderson	4.0	0.2591	0.0937	535	359
15	Williamston	15	Anderson	24.3	0.0066	0.0100	14	38
16	Williamston Rural	16	Anderson	22.2	0.0068	0.0102	14	39
17	Abbeville	17	Abbeville	25.9	0.0083	0.0116	17	44
18	Amtre-Lowdesville	18	Abbeville	14.0	0.0163	0.0173	33	67
19	Calhoun Falls	19	Abbeville	21.8	0.0075	0.0109	16	42
20	Donalds	20	Abbeville	23.8	0.0056	0.0091	12	35
21	Due West	21	Abbeville	22.0	0.0075	0.0108	15	42
22	Conestee	22	Greenville	36.4	0.0034	0.0067	7	26
23	Fountain Inn	23	Greenville	39.6	0.0024	0.0053	5	21
24	Highland	24	Greenville	36.7	0.0031	0.0063	6	24
25	Greenville	25	Greenville	39.6	0.0075	0.0109	15	42
26	Greenville East	26	Greenville	42.1	0.0041	0.0076	9	29
27	Greenville North	27	Greenville	42.5	0.0039	0.0073	8	28
28	Greenville SWest	28	Greenville	35.4	0.0077	0.0110	16	42
29	Greer	29	Greenville	49.5	0.0024	0.0054	5	21
30	Paris	30	Greenville	44.3	0.0029	0.0061	6	24
31	Piedmont	31	Greenville	28.7	0.0059	0.0093	12	36
32	Riverside	32	Greenville	42.3	0.0041	0.0076	8	29

OBS	CCD	CCD Number	County	Distance	IN ^A _i	NON ^A _i	In-Movers	Non-Movers
33	Simpsonville	33	Greenville	38.8	0.0033	0.0065	7	25
34	Slater	34	Greenville	48.5	0.0015	0.0040	3	16
35	Taylors	35	Greenville	44.9	0.0027	0.0058	6	22
36	Tigerville	36	Greenville	30.8	0.0036	0.0069	7	27
37	Travelers Rest	37	Greenville	45.6	0.0024	0.0054	5	21
38	Woodville	38	Greenville	29.3	0.0044	0.0078	9	30
39	Greenwood	39	Greenwood	37.0	0.0055	0.0090	11	35
40	Greenwood East	40	Greenwood	39.6	0.0020	0.0049	4	19
41	Greenwood North	41	Greenwood	37.0	0.0030	0.0062	6	24
42	Greenwood West	42	Greenwood	34.8	0.0036	0.0069	7	27
43	Hodges	43	Greenwood	30.0	0.0053	0.0088	11	34
44	Kirksey	44	Greenwood	47.8	0.0011	0.0033	2	13
45	Ninety-Six	45	Greenwood	43.7	0.0022	0.0051	5	20
46	Troy	46	Greenwood	30.5	0.0028	0.0060	6	23
47	Clinton	47	Laurens	50.8	0.0026	0.0057	5	22
48	Cross Mill	48	Laurens	44.0	0.0017	0.0044	3	17
49	Gray Court	49	Laurens	40.8	0.0026	0.0057	5	22
50	Joanna	50	Laurens	54.3	0.0011	0.0033	2	13
51	Laurens	51	Laurens	43.7	0.0029	0.0061	6	23
52	Laurens Rural	52	Laurens	41.4	0.0021	0.0049	4	19
53	Princeton	53	Laurens	31.9	0.0037	0.0070	8	27
54	Watts Mills	54	Laurens	45.2	0.0017	0.0045	4	17
55	McCormick	55	McCormick	41.8	0.0023	0.0052	5	20
56	MT. Carmel	56	McCormick	28.1	0.0033	0.0065	6	25
57	Parksville	57	McCormick	51.1	0.0010	0.0031	2	12
58	Longcreek	58	Oconee	39.8	0.0015	0.0040	3	14
59	Mountain Rest	59	Oconee	40.8	0.0013	0.0038	2	15
60	Oakway	60	Oconee	22.1	0.0077	0.0110	16	42
61	Salem	61	Oconee	37.8	0.0022	0.0051	5	20
62	Seneca	62	Oconee	24.2	0.0078	0.0111	16	43
63	Seneca North	63	Oconee	27.8	0.0047	0.0082	10	31
64	Seneca South	64	Oconee	20.3	0.0106	0.0134	22	51
65	Walhalla	65	Oconee	44.9	0.0018	0.0045	4	17
66	Walhalla North	66	Oconee	41.6	0.0021	0.0031	4	19
67	Walhalla South	67	Oconee	46.7	0.0014	0.0040	3	15
68	Westminster	68	Oconee	27.5	0.0063	0.0098	13	38
69	Central	69	Pickens	24.2	0.0072	0.0105	15	40

TABLE 2 (continued)

OBS	CCD	CCD Number	County	Distance _c	IN ^A _i	NON ^A _i	In-Movers	Non-Movers
70	Clemson	70	Pickens	22.0	0.0127	0.0150	26	58
71	Easley	71	Pickens	33.6	0.0051	0.0086	11	33
72	Easley East	72	Pickens	38.1	0.0020	0.0049	4	19
73	Easley Rural	73	Pickens	31.1	0.0049	0.0084	10	32
74	Forest	74	Pickens	46.5	0.0011	0.0034	2	13
75	Liberty	75	Pickens	29.0	0.0050	0.0084	10	32
76	Pickens East	76	Pickens	42.3	0.0018	0.0046	4	18
77	Pickens West	77	Pickens	35.8	0.0038	0.0072	8	27
78	Six Mile	78	Pickens	30.1	0.0046	0.0080	9	31
79	Bowman	79	Elbert	19.1	0.0083	0.0115	17	44
80	Coldwater Creek	80	Elbert	13.8	0.0158	0.0170	33	65
81	Elberton	81	Elbert	18.2	0.0145	0.0162	30	62
82	Dove Creek	82	Elbert	21.8	0.0062	0.0097	13	37
83	Middleton	83	Elbert	18.4	0.0124	0.0147	26	56
84	Carnesville	84	Franklin	26.6	0.0051	0.0085	11	33
85	Lavonia	85	Franklin	19.6	0.0103	0.0131	21	50
86	Royston	86	Franklin	20.8	0.0091	0.0121	19	47
87	Sandy Cross	87	Franklin	27.2	0.0032	0.0065	7	25
88	Bowersville	88	Hart	18.1	0.0088	0.0119	18	46
89	Hartwell N&S	89	Hart	19.0	0.0172	0.0180	36	69
90	Royston	92	Hart	37.5	0.0020	0.0048	4	18
91	Broad River	93	Stephens	26.4	0.0062	0.0097	13	37
92	Rock Creek	94	Stephens	29.9	0.0050	0.0084	10	32
93	Toccoa & Toccoa Creek	95	Stephens	28.9	0.0065	0.0099	13	38
TOTAL					100.0	100.0	2065	3835

percent of these, or 3,835, are expected to come from the local labor force and the remaining 2,065 workers will be in-migrants.

Movers and non-movers were distributed to a twelve county region around Anderson County which includes 95 CCDs. Population figures for CCDs were obtained from the 1970 Census of Population and estimates of airline distance from the NEC site to the major town in each CCD were made using geographic coordinates.

The impact area, shown in Figure 1, was defined to include counties of residence for workers who commuted to Anderson County, S. C., according to commuting data from the 1970 Census of Population. It was assumed that a nuclear energy center in Anderson County will draw workers at least from those counties supplying labor to Anderson County as of 1970. Examination of the commuter patterns of Catawba Plant workers reveals that some workers were willing to travel distances of over 50 miles one way, thus, this 12-county population estimate of the regional labor pool for a project of such magnitude is somewhat conservative.

The allocation of in-movers and non-movers to CCDs is presented in Table 2. For the purpose of comparison with 1970 Census commuter patterns to Anderson County (10), the results have been aggregated to the county level, and these are presented in Table 3. Based on a chi-square statistic calculated for the Catawba Plant data, it can be stated that the distribution of all commuters to York County is significantly different from the distribution of construction workers at the Catawba Plant. Thus, we can expect this will hold for workers at the Anderson NEC site as well, and we may generalize that application of the gravity model will yield a better estimate of construction worker locations than a regression-type projection of Census commuting data.

A major difference between commuting patterns for all types of workers in Anderson County and the pattern for NEC construction workers is that 92% of all workers in Anderson live in that county while only 38% of non-movers and 61% of in-movers are expected to live in Anderson County. A very similar pattern held true for the Catawba region as well, where 92% of all workers lived in York County with 42% and 65% of non-movers and in-movers, respectively, residing in the county.

In order to better compare general characteristics of the construction worker commuting patterns with those of all workers, a comparison of commuting patterns for construction workers and for all types of Anderson County workers is also presented in Table 3. This includes the percentages of workers residing in each county outside of Anderson. Contrasting the allocations of in-movers and non-movers with all 1970 commuters reveals several general characteristics which appear to differ significantly.

As has been noted in similar studies, there is a tendency for both in-mover and non-mover construction workers to travel further to work than other types of workers (5) (8). Only 8.9% of 1970 commuters travel over 30 miles to work while 32.3% and 32.9% of in-movers and non-movers to the Anderson region are expected to do so. This of course, is partially because of the nature

TABLE 3
Comparison of Commuting Patterns of Construction Workers to NEC with all Commuters to Anderson Co., 1970.

County	1970 Population	Centroid distance to Anderson centroid (miles)	1970 Commuters		Projected NEC Workers			
			Number	Percent of total living outside Anderson Co.	Number in-movers	Percent in-movers living outside Anderson Co.	Number non-movers	Percent non-movers living outside Anderson Co.
Abbeville, SC	21,112	27.6	444	15.5	94	11.6	230	9.6
Anderson, SC	105,474	NA	33,939	—	1,258	—	1,452	—
Elbert, GA	17,262	30.3	51	1.7	119	14.7	266	11.1
Franklin, GA	12,784	26.3	42	1.5	58	7.2	155	6.5
Greenwood, SC	49,686	35.2	106	3.7	53	6.5	194	8.1
Greenville, SC	240,546	27.1	916	32.0	136	16.8	464	19.4
Hart, GA	15,814	19.8	365	13.1	58	7.2	134	5.6
Laurens, SC	49,713	36.1	78	2.7	38	4.7	161	6.8
McCormick, SC	7,955	47.1	18	0.6	14	1.7	58	2.4
Oconee, SC	40,728	12.5	375	15.9	99	12.3	309	13.0
Pickens, SC	58,956	25.6	454	0.2	100	12.4	305	12.8
Stephens, GA	20,331	39.2	6	0.0	37	4.6	108	4.5
Total workers			36,794		2,065		3,835	
Total workers residing outside Anderson County			2,855	100	807	100	2,383	100
Percent commuting over 30 miles				8.9		32.2		32.9
Percent residing in counties over 100,000				32.0		16.8		19.4
Percent residing in counties between 40,000 and 100,000				35.4		35.9		40.7
Percent residing in counties under 40,000				32.6		47.3		39.9
Percent residing in Georgia				16.5		33.7		27.7

of construction work. Construction workers cannot choose the location of large projects at which they are employed, nor are they usually able to move each time a new project is begun. The NEC is of such a size, and the time period over which it will be constructed is so long, that one would expect in-movers to commute much shorter distances; however, the allocation to the Anderson region unfortunately does not reflect such a tendency.

Construction workers also differ from all types of commuters in the size of the counties in which they reside. Only 16.8% and 19.4% of in-movers and non-movers, respectively, reside in counties with over 100,000 population (only Greenville and Anderson Counties were over 100,000), while 32% of 1970 commuters lived in such an area. Rather, a larger percentage of construction workers tended to locate in smaller size counties. This tendency was most pronounced for the in-movers, 47.3% of whom are projected to live in counties of less than 40,000.

Another characteristic of NEC construction workers of considerable importance to the Anderson Region is the proportion of workers expected to locate in Georgia. While only 16.5% of 1970 commuters to Anderson County live in Georgia, 33.7% of the in-movers and 27.7% of non-movers are projected to live there. There may be some over-estimation of the workers expected to live in Georgia because the method used to calculate distances ignores the extra travel required to reach bridges crossing the lakes on the Savannah River, the boundary between South Carolina and Georgia; thus, distances from locations in Georgia to the NEC site are understated.

Aggregation to the county level is necessary to make a comparison with available census data on commuters, and although considerable detail is lost, such a comparison highlights several characteristics that establish a basis from which additional study may begin.

SUMMARY AND CONCLUSIONS

To accurately assess the impact of any new industry in a region, the residential location of new workers must be estimated. This need is of considerable importance when a large activity such as the nuclear energy center is anticipated. This paper presents an application of a gravity model designed to estimate future residential patterns of workers at the Anderson County, S. C., Nuclear Energy Center based upon survey data for workers at the Catawba Plant in York County, S. C.

A statistically significant model was obtained using only CCD population and distance to the plant site. The equations estimated reflected the varying importance which in-movers and non-movers attach to the distance and population variables. A broad comparison of the distribution of all commuters with that of construction workers reveals differing locational behavior and indicates characteristics which merit further study.

Further work on the Catawba model particularly with non-movers, might include further testing of weights, which account for variables such as distance

to population centers of various sizes, unemployment rates, availability of alternative employment, etc. Also, for application to the Anderson region, adjustments to the distance figures, from Georgia counties especially, would be useful.

REFERENCES

1. Borez, Judith A. *The Use of Gravity Models to Distribute Power Plant Construction In-Migrants*, Oak Ridge, TN, Oak Ridge National Laboratory, December, 1977.
2. Chalmers, James A. "The Role of Spatial Relationships in Assessing the Social and Economic Impacts of Large-Scale Construction Projects", *Natural Resources Journal*, Vol 17, 1977.
3. Harris, C. D. "The Market as a Factor in the Location of Industry in the United States", *Annals of the Association of American Geographers*, Vol. 44, No. 5, December, 1954.
4. Henry, Mark S. *The Economic-Demographic Impact of a Nuclear Energy Center - A Methodological Discourse and Application to the Anderson County, S. C., Site*, Clemson University, Department of Agricultural Economics and Rural Sociology, February, 1980.
5. Hertsgaard, T., et. al. *The REAP Economic-Demographic Model - Technical Description* (Bismark ND: Regional Environmental Assessment Program), 1977.
6. Hua, Chang-i and Frank Porell. "A Critical Review of the Development of the Gravity Model", *International Regional Science Review*, Vol. 4, No. 2, 1979.
7. Isard, Walter. *Methods of Regional Analyses*, Cambridge, MA, MIT Press, 1960.
8. Leholm, Arlen G., et. al. "Economic Impacts of Construction and Operation of Coyote Station #1 Electrical Generation Plant and Expansion of Coal-Handling Facilities at the Beaulieu Mine of Knife River Coal Compact", North Dakota State University, Fargo, North Dakota, June, 1977.
9. Murdock, Steve H., James S. Wieland and F. Larry Leistritz. "An Assessment of the Validity of the Gravity Model for Predicting Community Settlement Patterns in Rural Energy-Impacted Areas in the West", *Land Economics*, Vol. 54, No. 4, 1978.
10. S. C. Employment Security Commission. *Commuting Patterns for South Carolina Counties 1970 Census Data*. Columbia, S.C., April, 1973.
11. Stouffer, Samuel A. "Intervening Opportunities: A Theory Relating Mobility and Distance", *American Sociological Review*, Vol. 5, No. 6, December, 1960.
12. Unpublished data from Duke Power Company, Catawba and Cherokee Nuclear Plant Construction Work Forces Survey, 1977 and 1978.
13. Wieland, James S., F. Larry Leistritz, and Steve H. Murdock. "Characteristics and Residential Patterns of Energy-Related Work Forces in the Northern Great Plains", *Western Journal of Agricultural Economics*, Vol. 4, No. 1, 1979.
14. Wizard Research and Development Group, Inc. "Models and Methodologies for Assessing the Impacts of Energy Development", Washington, D.C., June, 1977.