AN APPROACH FOR THE ESTIMATION OF AGGREGATE POTENTIAL TELECOMMUTING DEMAND

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Abstract Development of technology has made possible the invention of innovative and modern methods to partially solve the problems caused by traffic congestion through decreasing the need for physical transportation; one such method being telecommuting. Although, research has been conducted to model employees' and employers' attitude towards telecommuting at micro levels, few predictions have been reported regarding its aggregate demand at the macro level of a city, generally because of the complexity and multi-dimensionality of the subject. In this paper, an approach for the estimation of potential aggregate telecommuting demand is proposed to partly fill the gap in the literature; and applied for the city of Tehran, Iran, using a 3-level generalization process to compensate for the incompleteness of the unattainable vast and expensive data. In the first level of the proposed approach, the matrix of average potential telecommuting demand for 36 job categories, defined by 6 different organizational positions and 6 different organizational units, is derived from a 670-sized sample. In the second level, the data of 14 percent of the government employees are collected despite the effort of aiming for the 100 percent and hence, in the third level, the geographic distribution of all government employees with telecommuting potential is determined. Results of this research regarding potential telecommuting demand for the city of Tehran show that 53,898 out of 148,551 government employees (about 36 percent) are able to participate in telecommuting programs on a daily basis, removing 53,898 peak hour work trips on a daily basis which is equivalent to 269,490 employees quitting their commute trip to work one day per week. Although based on rather strong assumptions, forced by the limitation of data, the approach is implemented for Tehran.

Keywords telecommuting, aggregate demand, transportation engineering.

چکیده توسعه فناوری روش‌های نوینی را (مانند دورکاری) برای حل معضل ترافیک از طریق کاهش نیاز به سفر فیزیکی امکان‌پذیر کرده است. اگرچه تلاش‌هایی برای مدل‌سازی رفتار کارمندان و کارفرمایان نسبت به دورکاری در سطح خرد انجام شده است، ولی پیش‌بینی‌های اندکی برای تقاضای کلان آن در سطح یک شهر، عموماً به خاطر چندوجهی بودن و پیچیدگی‌های موضوع صورت گرفته است. در این مقاله در تلاشی هرچند اولیه برای رفع این کمبود، رویکردی برای برآورد تقاضای کلان دورکاری در سطح شهر تهران پیشنهاد و به‌کار بسته می‌شود که شامل یک فرآیند تعمیم سه مرحله‌ای جهت جبران نقص موجود در داده‌ها و اطلاعات قابل دست‌یابی است. در سطح اول، ماتریس میانگین تقاضای دورکاری برای ۳۶ دسته شغل (به تفکیک ۶ واحد سازمانی و ۶ پست سازمانی) بر اساس نتایج یک آمارگیری با نمونه ۶۷۰ تایی برآورد می‌شود. در سطح دوم، داده‌های ۱۴ درصد از کارمندان دستگاه‌های اجرایی شهر تهران گردآوری شد. با توجه به عدم امکان گردآوری ۱۰۰ درصد این داده‌ها، در سطح سوم توزیع جغرافیایی تمام کارمندان دارای پتانسیل دورکاری تعیین شد که بر اساس آن با استفاده از رویکرد پیشنهادی این مقاله، برآوردی از تقاضای کلان شهر تهران صورت گرفت. نتایج نشان می‌دهد که از بین ۱۴۸۵۵۱ کارمند بخش دولتی و عمومی، ۵۳۸۹۸ نفر (حدود ۳۶ درصد) می‌توانند به طور روزانه در برنامه دورکاری شرکت کنند، که باعث حذف همین تعداد سفر کاری در ساعت اوج ترافیک

صبح می‌گردد. به عبارت دیگر، اگرچه مبتنی بر فرض‌هایی به خاطر عدم امکان دستیابی به داده‌ها، حدود ۲۶۹۴۹۰ کارمند قابلیت دورکاری یک روز در هفته را دارند.

1. INTRODUCTION

The development of cities, the growth in population and the fact that the number of private autos is increasing every day, result in an increase in traffic congestion that causes a waste in time and energy. Alleviation of traffic congestion through planning and management of transportation is one of the main concerns of transportation and urban researchers and planners. In large cities, particular effort has been, and still is being, made to limit the use of private autos as a main remedy and encourage the use of public transportation to alleviate traffic problem.

Development of technology has made possible the invention of innovative and modern methods to solve, at least partially, the problems caused by traffic congestion, through elimination or decreasing the need for physical and conventional transportation. One such method introduced about 30 years ago, gaining more inertia due to developing ICT (information and communication technologies) is telecommuting. From the very beginning of the advent of formal telecommuting in America, as early as 1976, different predictions were reported regarding its demand partly unrealistic, divergent or inconsistent, generally because of the complexity and multi-dimensionality of the subject [1] (social, economic, cultural and psychological, to name a few) and also due to optimistic and not enough detailed procedures and computations [2].

Telecommuting as defined by Niles, is *sending the work to the workers, instead of sending the workers to work; the partial or total substitution by telecommunications technology, possibly with the aid of computers, for the commute to and from work* [3]. Telecommuting can be implemented in two general ways, depending on the place substituting the conventional work place or office, as home-based and center-based telecommuting. Telecenters, as places specially and specifically designed for this purpose, hold (among others) the advantage that home and work issues are kept apart so that the atmosphere is that of formal work, unlike home-based, which mainly suffers from this issue. Another major issue is the amount of telecommuting (generally reported in number of days per week) that different employees can actually adopt, regarding different factors, particularly their job and organizational characteristics. This paper is based on the results of the first official research effort to estimate potential telecommuting demand at the aggregate level of a metropolitan area, here Tehran, the capital city of Iran [4].

Previous researches [5, 6] attempting to model telecommuting suitability was conducted on a much smaller sample (245 size) to illustrate mainly the implementability of the concept of abstract job approach to model telecommuting feasible and suitable demand to identify significant job tasks. Multi-stage heuristic techniques to overcome tradeoffs between attributes have lead to reliable results [7]. Although, research has been conducted to model employees' and employers' attitude toward telecommuting at micro levels, there is a gap for scientific research to estimate the aggregate potential demand for telecommuting at macro levels, especially in a developing country. This paper, aiming to fill this gap, estimates feasible telecommuting demand using a heuristic approach at the macro level of the city of Tehran. After reviewing the literature in the field, the process of data gathering and survey administration will be discussed, and a heuristic approach will be presented to generalize the results obtained from the sample to population levels 1 and 2 (because of the lack of full cooperation of the governmental organizations) by the use of the heuristic method (three-level generalization process). The paper ends with the conclusions and suggestions for further research.

2. LITERATURE SURVEY

Although telecommuting is not yet formally practiced in Iran, and there are not many companies that have adopted telecommuting yet, it has been brought to notice, particularly due to the traffic congestion problem of Tehran and its

related heavy transportation costs. There are different estimations of telecommuters around the world, partly because there is not a standard definition of telecommuting [8].

In an effort to develop a methodology that combines academic and practitioner experiences within a theoretical framework that captures consumers' price responsiveness to diverse transportation options by embracing the most relevant trade-offs faced under income, modal price and availability constraints, Concas and Winters [9] evaluated some related case studies. In the case of the AT&T Telework Program, which initiated in 1992 to encourage its managers to work from home, it was observed that beginning with modest forecast predictions of about 10 percent in 1992; by early 2000, the program had grown to an extent where nearly 56 percent of its managers telecommuted at least once a month while 27 percent telecommuted at least once a week. In their evaluation of the AT&T Telework Program, they noticed that the fact-sheet of the AT&T annual survey of its employees on telework indicated that in 2000, AT&T's employee telework program resulted in 56 percent of participants teleworking at least one day per month.

In a survey [10] of the City of Tucson, Arizona, due to and emphasizing the notable achievement and the fact that it ranks third in the United States on the 2006 Digital Cities Survey (which examines how city governments are using digital technologies to better serve their citizens and streamline operations), it is aimed to use emerging technologies to communicate with the residents and businesses of Tucson. To build upon this achievement, the City is researching methodologies to increase the affordability and availability of connectivity services for residences and small businesses. Based on the results of this survey, with the sample size of 249, it is concluded that nearly one-half of businesses allow telecommuting, and another three percent indicate that they were likely to allow telecommuting within the next two years.

In an attempt to analyze the reduction in overestimation in forecasting telecommuting as a TDM Policy, Tal [11] posits that overestimates are virtually inevitable in forecasting the effect of new policies that aim to change travel behavior, but these biases eventually decline over time. He observes that 1- the sources of overestimated forecast are the prediction tools used, and the ways in which modelers use these tools and 2- the sources of the reduction in overestimation are the changes made to the modeling tools results from knowledge and data gained over time.

In a research aiming to establisha formal telework/telecommuting program for North Carolina State employees with the goal to improve the economy and efficiency of State government operations, Campbell [12] conducted a survey to determine current agency use of working-from-home positions and a corresponding review of research on the use of telecommuting. Based on survey results, state agencies employed telework for only 2.2 percent of positions (726 out of 32,947), and the State could receive $23,297,416 in benefits from a telework/ telecommuting program, involving 5 percent of eligible state employees. The actual benefit to the State depends on the number of employees participating in the program. According to the Office of State Personnel, there are 85,288 state employees (excluding all exempt positions within the University system) who would potentially be telecommuters. The amount of benefits gained depends on the number of employees participating and the number of days each week the employees telecommute. It has been calculated for 1 to 5 percentages of total employees.

Millard [13] considers it an almost astonishing awareness that by the year 2000, the European teleworkers were over 4.5 million, corresponding to 3 percent of the workforce, while till some months ago, telework itself seemed to be doomed to represent one of the post-industrial society's chimeras as well. He summarizes that each country has its a bit peculiar history of telework development: in the US it was at first dragged along by the antipollution rules, but more recently the phenomenon of the home office and home micro-business through the Internet has driven the number of teleworkers to over 10 million. In Sweden, where teleworkers are 5 percent of the population, distance work has spread thanks to the so-called "telecottage movement". In Ireland, Call centers (and telecottages) were the bearing axes of telework's spread, which at present involves over 6 percent of the employed. In the UK, telework growth seems to have been affected more by the

large amount of self-employed teleworkers, professionals who use the Internet to keep in touch with customers or acquire new ones, rather than by telecottages (which, however, are several hundreds). In Italy, where telework concerns only a minority - a bit less than 250,000 teleworkers -, and it is hard to find original examples and best practices, a new original way now seems to be opening up: the public sector is dragging the private [13].

In a case study of telework in Italian public administration surveyed in Perugia by Patrizio Di Nicola & Annamaria Vallarelli, 279 valid questionnaires were collected representing the complete staff as for age and length of service. They believe since teleworking is not suitable for everybody, it should be voluntary and the choice of working far from the office should be eventually reversible. Therefore, there are people who would like to try it, but cannot because of the kind of work they do (more than 30 percent). On the other side, there are some others who technically speaking could telework but do not intend to leave their work environment, clearly dear to them (near 27 percent). Therefore against a theoretic willingness to telework expressed by more than 40 percent of the interviewees, the ones who can and at the same time want to telework decrease to a bit little less than 12 percent of the persons questioned [13].

3. DATA COLLECTION AND SURVEY ADMINISTRATION

Since data collection at the level of a city (particularly in a developing country) confronts many barriers and obstacles, a good deal of effort was made, and at the same time, some assumptions were needed to make possible this estimation with acceptable error level. A lack of complete and impeccable cooperation of organizations lead to the gathering of the data at three levels, instead of the standard and conventional two levels (sample and population) normally used. Hence, data gathering and survey administration became an even more important section of the research since one objective of the research was to implement the proposed approach and estimate the aggregate feasible demand for the city of Tehran with as much accuracy as possible, regarding the circumstances. Thus, in the first level, data of 670 government employees in Tehran was gathered through an in-person interview to brief the respondents and complete the questionnaires comprising their job, organizational, personal, work trip characteristics and telecommuting feasibility.

The second level of information contains employees' job and organizational characteristics needed to estimate telecommuting demand. It was hoped and so planned to cover the whole statistical population, however of all the ministries with whom correspondence were made, about 50 percent did not reply at all. For these missing data, further correspondence was made with the "Management and Planning Organization" the organization responsible for the organizational chart of the government sector. From among these, another 30 percent was collected. Eventually 21,284 records were obtained which is approximately a 10 percent sample of the desired statistical population. Finally, the third level of information includes all the government employees, but with less detail: only the addresses of these organizations. Figure 1 depicts the relationship between these three levels and their main characteristics.

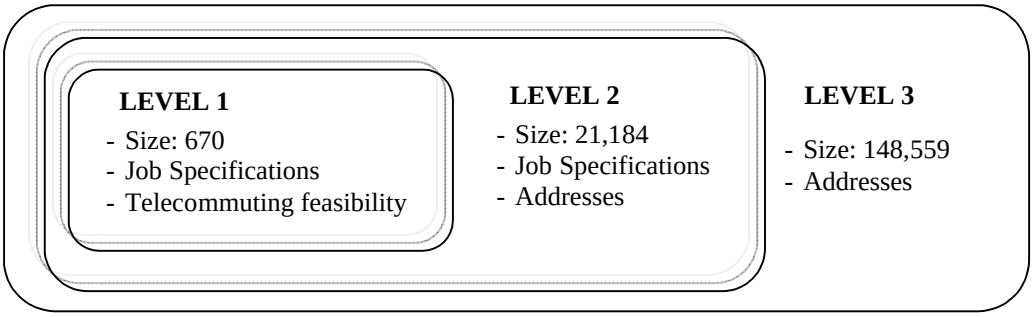

Figure 1. The three levels of data gathered in the research

Job and organizational characteristics and data available at large scale for different jobs according to the "Management and Planning Organization" of Iran are: 1- organizational position which shows the position of the employee and its level in the organization (denoted here by the superscript **p)**, 2- organizational unit or office type which is a smaller section of an organization responsible for some homogeneous tasks fulfilling partly the overall aim of the organization (denoted here by the superscript **u**), and 3- job category, a set of job classes holding similar tasks, education and experience (denoted by the superscript **c**). The third element (**c**) proved to be insignificant using correlation analysis and was thus eliminated from the models. Tables 1 and 2 show the definition and description of the two significant factors, distinguishing employees' job characteristics, namely organizational positions and units, respectively.

TABLE 1. Organizational positions and their description as used in this study

No.	Organizational position	Description
1	Junior employee	High school graduate or university degree below bachelors
2	Senior employee	At least undergraduate education with usually less than 10 years experience
3	Very senior employee	At least undergraduate education with at least than 10 years experience (usually)
4	Lower manager	Directly responsible for employees not holding a management degree (also referred to as supervisor)
5	Middle manager	responsible for lower managers and (indirectly for) their employees
6	Other *	Any position except for the above

* Due to the very low frequency of the other organizational positions, they were aggregated in this category

TABLE 2. Organizational units and their description as used in this study

No.	Organizational unit	Description
1	Division	Generally federal parts of the government with mainly executive tasks and responsibilities
2	Deputy's office	Highest level of organizational unit after ministries with mainly executive tasks and responsibilities
3	Province/ state offices	Larger divisions located in the provinces as the local government offices with executive tasks
4	Office	Generally federal parts of the government with mainly study, research or training tasks and responsibilities
5	Center	Like an office but more independent due to its more centralized and national role
6	Other [a]	Any unit except for the above

[a] Due to the very low frequency of the other organizational units, they were aggregated in this category

4. METHODOLOGY

Since there are 3 levels of data with different data and variable contents available, and the objective is to ultimately estimate potential telecommuting demand at level 3 (Tehran city), the following is proposed.

$$DTC^1 = \sum_{p=1}^{P}\sum_{u=1}^{U} E^{p,u,1} \times F^{p,u,1} \quad (1)$$

$$DTC^2 = \sum_{p=1}^{P}\sum_{u=1}^{U} E^{p,u,2} \times F^{p,u,1} \quad (2)$$

$$DTC^3 = \sum_{p=1}^{P}\sum_{u=1}^{U} E^{p,u,3} \times F^{p,u,1} \quad (3)$$

Where:

DTC^1: demand for telecommuting at level 1;

DTC^2: demand for telecommuting at level 2;

DTC^3: demand for telecommuting at level 3;

$E^{p,u,1}$: number of employees working in position **p** and unit **u** at level 1;

$E^{p,u,2}$: number of employees working in position **p** and unit **u** at level 2;

$E^{p,u,3}$: number of employees working in position **p** and unit **u** at level 3, and

$F^{p,u,1}$: feasible telecommuting demand for employees working in position **p** and unit **u** at level 1 (days per week).

The two job characteristics found significant in telecommuting demand are: organizational positions and organizational units denoted by superscripts **p** and **u,** respectively. Each of these factors takes six different values or sub-categories as indicated in Tables 1 and 2.

Telecommuting demand at all levels is calculated as the summation of the product of its two components: number of employees in each class and telecommuting feasibility per each class of employees. Feasibility of telecommuting for each employee class (with specific job characteristics) was solely surveyed at level 1 by questioning their managers who are aware of their job tasks. Table 3 shows the variety of 670 employees at level 1 as a 6x6 matrix in different job categories including their average telecommuting feasibility. For example, the organizational position '*senior employee*' in the organizational unit '*office*' has 200 frequencies in which the average estimate or judgment of their managers leads to 1.91 days of telecommuting per week.

As shown in Equations (1) to (3), this matrix (telecommuting feasible demand by organization) is assumed to hold for all levels, and is thus also used at levels 2 and 3. Level 2 which was aimed to collect job specifications for the whole employees working in Tehran's governmental organizations, prepared the information about 21,184 people as shown in Table 4. To estimate telecommuting

TABLE 3. All information in level 1 (matrixes $E^{p,u,1}$ and $F^{p,u,1}$ together)

Position \ Unit	division		deputy's office		state office		office		center		other		Sum/ Average	
	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$	$E^{p,u,1}$	$F^{p,u,1}$
junior employee	16	1.0	3	2.0	5	3.0	46	1.8	3	1.0	27	0.96	100	1.49
senior employee	39	1.5	3	1.67	53	2.45	200	1.9	39	1.57	30	0.93	364	1.83
very senior employee	3	2.0	1	3.0	12	2.1	21	2.2	8	2.0	6	1.33	51	2.04
lower manager	16	1.5	1	3.0	5	1.4	25	2.2	10	0.6	16	1.44	73	1.62
middle manager	7	1.43	1	2.0	3	1.33	24	1.54	4	1.0	3	0.33	42	1.38
other	0	0.52[a]	0	0.52[a]	1	3	20	0.74	10	0.3	9	0	40	0.52
Sum/ Average	81	1.42	9	2.11	79	2.33	336	1.84	74	1.26	91	0.94	**670**	**1.66**

[a] There were no observations for this cell, so the average of the row was considered as its telecommuting suitability

adoption at this level, corresponding elements in Table 1 and Table 2 were multiplied and added as in Equation (2). A total of 38,431 days per week of telecommuting is estimated to be suitable at this level (Table 5).

For the city of Tehran (level 3), the estimation process is more complicated; since not all ministries were able to have full cooperation in data gathering stage. It is assumed that the job distribution at level 2 holds for the city (Table 6). This generalization of the matrix E is based on the 21,184 pieces of data gathered at level 2 and used for the 148,559 population (almost 14 percent sample size) of Tehran government employees.

TABLE 4. Job frequency distribution at level 2 ($E^{p,u,1}$)

Position \ Unit	division	deputy's office	state office	office	center	other	Sum	Percentage
junior employee	981	304	1423	577	231	324	3,840	18
senior employee	1899	758	2455	3422	584	799	9,917	47
very senior employee	543	145	711	789	200	131	2,519	12
lower manager	524	187	490	708	163	152	2,224	10
middle manager	205	63	230	394	27	88	1,007	5
other	633	101	505	146	134	158	1,677	8
Sum	4,785	1,588	5,814	6,036	1,339	1,652	21,184	100
Percentage	23	7	27	28	6	8	100	

TABLE 5. Telecommuting estimation at level 2 based on job characteristics

Position \ Unit	division	deputy's office	state office	office	center	other	Sum	Percentage
junior employee	981	608	4269	1044	231	311	7,444	19
senior employee	2867	1266	6015	6536	917	743	18,344	48
very senior employee	1086	435	1479	1728	400	174	5,302	14
lower manager	786	561	686	1558	98	219	3,907	10
middle manager	293	126	306	607	27	29	1,388	4
other	329	53	1515	108	40	0	2,045	5
Sum	6,343	3,048	14,270	11,581	1,713	1,476	38,431	100
Percentage	17	8	37	30	4	4	100	

TABLE 6. Job configuration at level 2 (percent)

Position \ Unit	division	deputy's office	state office	office	center	other	Sum
junior employee	4.6	1.4	6.7	2.7	1.1	1.5	18.1
senior employee	9.0	3.6	11.6	16.2	2.8	3.8	46.8
very senior employee	2.6	0.7	3.4	3.7	0.9	0.6	11.9
lower manager	2.5	0.9	2.3	3.3	0.8	0.7	10.5
middle manager	1.0	0.3	1.1	1.9	0.1	0.4	4.8
other	3.0	0.5	2.4	0.7	0.6	0.7	7.9
Sum	22.6	7.4	27.4	28.5	6.3	7.8	100

5. APPLYING THE MODEL FOR THE CITY OF TEHRAN

Predicting aggregate telecommuting demand at the level of a city is a main objective of urban and transportation policy makers and planners and the concern of this paper. The schematic approach to calculate the aggregate telecommuting demand and its constituent stages are depicted in the flow chart presented in Figure 2.

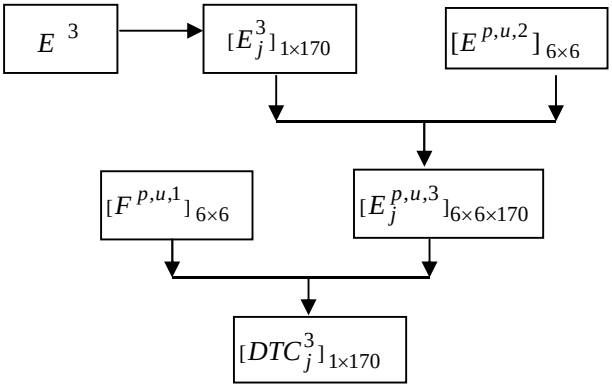

Figure 2. Stages in the approach to calculate aggregate telecommuting demand

According to its Comprehensive Transportation and Traffic Studies [14], Tehran is divided into 560 traffic zones in its transportation master plan.

Adding the subscript **j** denoting the traffic analysis zone (TAZ) of the current conventional work place, Equation (3) can be transformed into Equation (4) at the first stage with a partial difference. Because of the 5 workdays in a week, the estimation should be divided by 5 in order to stabilize its minimum traffic impacts in the network. Thus, the process which was used in level 2 resulting in Table 5 is also utilized here for level 3.

$$DTC_j^3 = \sum_{p=1}^{P}\sum_{u=1}^{U} E_j^{p,u,3} \times F^{p,u,1} / 5 \qquad j = 1,...,170 \qquad (4)$$

In which,

DTC_j^3 : demand for telecommuting at level 3 potential for TAZ **j** of conventional office, and

$E_j^{p,u,3}$: number of employees working in TAZ **j** , position **p** and unit **u** at level 3.

Searching for addresses of the current conventional offices at level 3 resulted in 170 zones (out of the 560 zones of Tehran), where government organizations are located. For each of these 170 zones containing 148,559 employees, a job frequency distribution matrix was estimated similar to Table 4 of level 2 by exploiting job distribution in Table 6 to have an estimate of $E_j^{p,u,3}$. Equation (4) can now be applied to estimate current telecommuting potential demand in each zone (DTC_j^3).

6. AGGREGATE POTENTIAL TELECOMMUTING DEMAND MODEL RESULTS

Results of this research regarding potential telecommuting demand for the city of Tehran showed that 53,898 out of 148,551 government employees (about 36 percent) are able to participate in telecommuting program on a daily basis, eliminating 53,898 peak hour work trips. The geographic distribution by zone is shown in Table 7. Quiet expectedly, there is a noticeable correlation between a zone's occupation level and telecommuting demand.

7. CONCLUSION

In this paper, an approach for the estimation of potential telecommuting demand was proposed and implemented for Tehran, Iran using a 3-level generalization process to compensate for the incomplete data. In the first level, the matrix of average telecommuting feasibility for 36 job categories defined for 6 different organizational positions and 6 different organizational units was derived from a 670-sized sample and applied in both the second and third levels. In the second level, despite the effort to collect the data for the whole government employees, the data of only 14 percent of the population (21,184 employees) was collected. In the third level, the geographic distribution of government employees having telecommuting potential was determined (148,559 employees).

TABLE 7. Telecommuting estimation for the 3rd level based on job characteristics

Zone	workers	tele-commuters	Zone	workers	tele-commuters	Zone	workers	tele-commuters	zone	workers	tele-commuters	zone	Workers	tele-commuters
1	1816	659	88	1865	677	167	3317	1203	274	201	73	429	115	42
2	1366	496	89	172	62	168	172	62	275	627	227	431	64	23
3	130	47	108	367	133	169	249	90	281	192	70	432	64	23
13	159	58	111	159	58	170	3703	1344	284	1437	521	434	87	32
14	2131	773	113	360	131	177	2555	927	285	159	58	437	1924	698
15	992	360	116	637	231	178	38	14	286	1694	615	438	130	47
17	159	58	118	3544	1286	179	552	200	288	115	42	443	1864	677
18	2171	788	119	4826	1751	180	242	88	293	1865	677	445	89	32
21	1865	677	120	3701	1343	181	196	71	304	79	29	446	414	150
27	1113	404	121	3077	1116	191	375	136	305	159	58	465	130	47
28	2253	817	123	2024	734	193	172	62	306	130	47	481	130	47
30	87	32	124	1202	436	198	130	47	315	113	41	484	9352	3393
31	172	62	125	545	198	207	2476	898	316	912	331	485	172	62
32	305	111	126	502	182	215	130	47	318	543	197	504	130	47
33	644	234	127	1716	623	229	130	47	326	543	197	506	1865	677
34	159	58	128	149	54	230	862	313	332	1865	677	515	159	58
35	769	279	129	888	322	231	1100	399	335	129	47	519	172	62
36	144	52	130	404	147	234	233	85	336	130	47	525	159	58
39	235	85	131	3004	1090	236	7	3	344	182	66	526	159	58
41	1865	677	136	271	98	240	69	25	359	1865	677	529	134	49
42	130	47	137	295	107	248	355	129	360	172	62	530	757	275
43	1865	677	138	481	175	249	8	3	368	130	47	531	130	47
46	492	179	139	0	0	257	2220	805	371	159	58	532	129	47
50	13	5	141	917	333	260	61	22	373	305	111	533	1865	677
52	779	283	144	993	360	261	59	21	381	1995	724	535	775	281
53	305	111	147	1152	418	263	130	47	389	159	58	537	104	38
54	159	58	149	671	243	264	407	148	394	543	197	538	160	58
58	1816	659	150	260	94	265	411	149	395	109	40	539	130	47
61	2318	841	153	88	32	266	1083	393	401	1865	677	545	274	99
65	2183	792	155	130	47	269	261	95	412	217	79	547	2625	952
66	1628	591	158	2107	764	270	28	10	414	1865	677	551	38	14
75	130	47	159	877	318	271	519	188	425	104	38	552	110	40
82	1865	677	162	159	58	272	2952	1071	427	172	62	557	744	270
84	130	47	166	3563	1293	273	113	41	428	172	62	559	3720	1350
Zones			170		workers			148,551			telecommuters			53,898

For estimating the trip distribution matrix of potential telecommuters, employees were distributed on their geographical places of work and residence. Then for each zone, the occupation matrix was formed by using the job configuration derived from the second level. The feasibility matrix of the first level was applied to each zone's job categories matrix and resulted in the telecommuting demand of each distribution zone (Table 7). Since the omitted trips to the CBD due

to center-based telecommuting are work trips during peak hours, telecommuting can influence the worst traffic period during the day. According to this study, on the average 53,898 work trips can be removed each day or 269,490 telecommuters will be quitting commuting to work one day per week.

Results of this paper regarding potential telecommuting demand for the city of Tehran showed that 53,898 out of 148,551 government employees (about 36 percent) are able to participate in telecommuting program on a daily basis, eliminating 53,898 peak hour work trips. The geographic distribution of potential telecommuters by zone is shown in Table 7. Quiet expectedly, there is a noticeable correlation between a zone's occupation level and telecommuting demand.

Besides the data limitation which made some assumptions inevitable to estimate telecommuting demand, it should also be noted that, the methodology applied in this study has the limitation that the distance from home to workplace does not influence the telecommuting feasibility of employees and also individual characteristics like age, gender, educational degree, and car ownership are not considered, which are suggested as areas of future research. Another next extension to the current research is the estimation of telecommuting trip distribution matrix to predict its impact on traffic on a large scale of a city with more details.

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