Gender difference in daily activity patterns, urban form, and intra-household interactions

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Abstract

One notable issue to deal with when capturing the individualism of travel behaviors is the gender difference. An extensive body of research has widely acknowledged that women and men exhibit quite different travel and activity patterns. For example, findings have suggested that women tend to invest more time to family-sustaining activities and that women make more family-sustaining trips yet fewer recreational trips. The primary focus of this study is to account for gender difference in travel behaviors. Particularly, the study attempts to understand how micro-level *household dynamics* and meso-level *urban form* may affect the activity patterns of women and men differently.

To test the hypotheses and the prototype model, the city of Santiago de Chile is chosen. Although the empirical results from this study do not conclusively confirm that either household dynamics or urban from constitute solid reasons for the gender differences in activity patterns, increasing females' bargaining powers and improving accessibility still remain a viable approach to empower women in Santiago de Chile. Moreover, it is found that traditional travel demand models without incorporating the power relation are less responsive to the change in household dynamics between spouses and thus tend to underestimate the travel demand of a transitional

society. This underestimation of travel demand would possibly affect the accessibility and mobility of the society adversely.

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Title: Professor of Urban Planning and Operations Research

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"A cheerful heart is good medicine, but a crushed spirit dries up the bones."

--Proverbs 17:22

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1. Introduction

As an important evaluation criterion of land use and transportation planning, accessibility denotes the ease with which activities can be reached. Accessibility is a multi-facet concept that requires attentions from both transportation system and land use system. In addition, accessibility also accounts for individual human agents and their decision-making under the external, structural settings. Therefore, accessibility can be taken as a function of the interactions between land use and transportation supply and travel demand decisions.

Travel decisions are an essential element of accessibility; they are often fundamental to the design of transportation demand management (TDM) strategies so that people's travel decisions can be influenced to reach desired accessibility goals (Meyer 1997). The modeling of individual, disaggregated travel decision-making is gaining increasingly attention. This human focus is particularly acute today with the growing need to evaluate short-term travel demand management (TDM) policies such as fuel tax and congestion-pricing. The existing statistically-based modeling approach can represent only long-term transport mitigation strategies such as transit extensions or other capital improvements; however, short-term non-capital improvements such as carpooling or congestion pricing cannot be so readily represented (Deakin et al. 2001). The ability to model individual activity behavior and interpersonal linkages between individuals is therefore necessary for the analysis of such TDM policies.

One notable travel behavior that requires travel demand analysis to go beyond group travel behaviors to consider individualism and interpersonal linkage is the gender difference in travel behaviors. An extensive body of research has widely acknowledged that women and men exhibit quite different travel and activity patterns. For example, findings have suggested that women tend to invest more time to family-sustaining activities (Mauch & Taylor 2007, Niemeier & Morita 1996, Hanson & Hanson 1980), that women make more family-sustaining trips yet

fewer recreational trips (Hanson & Hanson 1980, Hanson & Johnston, Rosenbloom 1987), and that employed women tend to have shorter commuting distances and times than employed men (Blumen 1994, Hanson & Johnston 1985, Hanson & Pratt 1990, Madden 1981).

The implication of accounting for the gender difference in travel demand models and being able to forecast the changes in gender difference in travel demands is profound. The planning process based upon the matching of transportation network supply to demand might result in failure to meet the efficiency and equity goals, if gender difference is not given its due attention. Overlooking gender difference in travel behavior can easily lead to equity consequences. For example, transportation and land use planning that are blind to the different transport needs and priorities of women and men are often criticized to place women's mobility and accessibility at stake (Moser 1989). In many developing countries, in particular, urban transport systems that are designed to serve daily commuting needs are faulted for their insensitivity to the travel demand of most women travelers, whose primary trip purposes are shopping or escorting (GTZ 2007). As for efficiency, failing to account for the reasons that give rise to the gender difference in travel behaviors such as social context, household interaction and individual preferences (or capabilities) may cause the under- or over-estimation of travel demand, which would adversely affect the accessibility and mobility of the society as a whole.

Actually, different travel behaviors between women and men are not fixed over time. As pointed out by Crane (2007), the average commute times of women and men in the U.S. were converging during the period of 1995-2005. In order to predict the future trend in gender difference in travel behaviors, one needs to dig into the reasons that account for the discrepancy between travel patterns of women and men. Therefore, this study makes two inquires:

- **Positive:** How to account for the gender difference in travel behavior in order to accurately project the future trend?
- **Normative:** How to promote the equity and efficiency of TDM strategies that aim to deal with the trend?

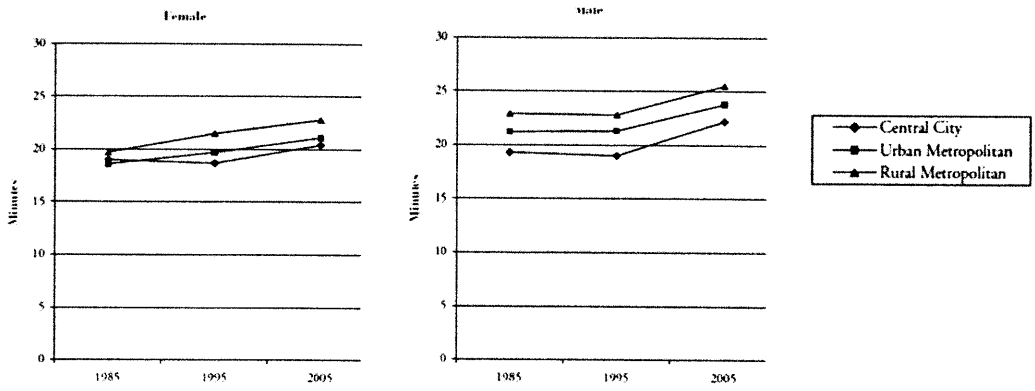


Figure 1.1Average commute duration by residence location (1995-2005)

(Source: Crane (2007))

In term of the positive inquiry, the intuitive explanation to these behavioral outcomes could simply come down to the gender variable. However, gender is a social construct that is tied to different familial and social roles played by men and women. Therefore, in order to reveal the causal underpinnings of gender difference, one needs to look beyond the indicator of gender to embrace a richer meaning of gender. This paper does not attempt to enumerate and test all the possible explanations that lead to the gender difference in travel behaviors. Due to the data limitation, I will focus primarily on understanding how micro-level *household dynamics* and meso-level *urban form* may affect the activity patterns of women and men differently (Section 3).

To operationalize the positive inquiry, numerous modeling challenges have to be overcome, particularly the challenges with modeling on household dynamics. This paper develops an activity-based collective model that builds on the premise that the outcomes of

household interactions are more or less governed by the power relations between couples in families (in Section 4). Typically, the one with the most bargaining powers may easily realize their individual interests or have a smaller share of family burdens. With the aid of a game-theoretic framework, the disproportionate influences that husbands have on wives are modeled (in Section 5).

To test the hypotheses and the prototype model, the city of Santiago de Chile is chosen. The city is critically posited to overcome its gender inequality problem that is believed to impede the city's effort to achieve economic development and poverty reduction (World Bank 2007). Based on a travel survey carried out in 2002, the model is applied to investigate the extent to which household dynamics and urban from contributes to the different activity patterns between spouses. Although the empirical results from this study do not conclusively confirm that either household dynamics or urban from constitute solid reasons for the gender differences in activity patterns (in Section 6), increasing females' bargaining powers and improving accessibility still remains a viable approach to empower women in Santiago de Chile. Moreover, building on the understanding of the effects of household dynamics on activity pattern choices, further steps to improve travel demand forecast models are discussed (in Section 7). It is found that traditional travel demand models without incorporating the power relation between spouses tend to underestimate travel demands and be less responsive to the change in household dynamics (in Section 8).

2. Literature review

2.1 The conceptualization of the causal inquiries on gender difference in travel behavior

Findings have suggested that women tend to exhibit different activity patterns from men; for example, they invest more time to family-sustaining activities (Niemeier & Morita 1996; Hanson & Hanson 1980), and employed women tend to have shorter commuting distances and times than employed men (Blumen 1994; Hanson & Johnston 1985; Hanson & Pratt 1990; Madden 1981; McLafferty & Preston 1991). Moreover, women also make more daily trips and use public transit more than men (Mauch and Taylor 1997; Hecht 1974; White 1986; McLafferty and Preston 1991; Sermons and Koppelman 2001).

To the extent that gender difference in travel behavior is a manifestation of gender inequality, approaches to cope with the differential behavioral outcomes of women and men are essential. After all, gender equality not only safeguards the basic human rights of women, but also is the necessary pathways to economic and social development (Sinha 2007).

Moreover, from the efficiency perspective, although controversies still prevail regarding if this intra-household inequality of the division of housework is efficiency-improving, a widely-accepted idea is that empowering women in families could confer many benefits to the entire society. In the human-capital theory, Becker (1991) posited that job specialization in a household (that is, one member of a household specializing in home production and the other specializing in work) brings out beneficial outcomes. Like the labor specialization in the market field, each person in the family finds their niche; therefore, the efficiency of the family as a whole is optimized. However, many scholars contested that allowing women to work is essential to help families to weather economic instability, as in face of economic shock, dual earners families are more resilient. In a similar vein, some also argued that the empowerment of women is necessary,

since female empowerment not only is beneficial to women per se but also has positive spillover effects to enhance the well-being of family members, particularly minor children (Seebens 2011). Because of this intra-household spillover effect, policies that only target at families rather than individuals may result in market failure. Moreover, worldwide evidence has indicated that the reduction in gender inequality often translates to greater economic growth and poverty reduction (World Bank 2007). Particularly, it is an essential matter to developing countries that are still struggling with poverty and unaccountable governments. In light of this, United Nations have integrated women's empowerment into their global and national efforts to achieve the Millennium Development Goals and sustainable development (United Nations 2010). Coordinated global and national efforts are made to integrate gender equality and women's empowerment into poverty reduction, democratic governance, and environment and sustainable development.

1. The existing explanations of gender difference in travel behavior

Various explanations can account for gender difference in daily activity pattern choices; they were broadly divided into two theoretical perspectives by Fuwa (2004): the macro-level social influences and the micro-level household dynamics[1]. The micro-level explanations posit that either time availability or relative powers determine the gender difference in travel decision outcomes (Kamo 1988, Shelton & John 1996). For example, Coverman (1985), England and Farkas (1986), and Hiller (1984) suggested that the availability of household members decides which household member takes on certain work. Becker (1991) pointed out that the gender differences in daily activity patterns are attributed to the different experiences and endowments

[1] Other alternative explanations also exist. For example, studies have found that the unique, intrinsic traits of women such as being weak in navigating (or way-finding) (Lawton 1994) or strong in environmentally consciousness may make women less likely to drive (Matthies 2002).

of human capital between spouses. Alternatively, Gronau (1986) and Becker (1991) argued that the wage plays a crucial role in the shaping of daily activity patterns. For example, men in dual earner families typically do less house-sustaining work than their wives because they earn more. This income gap further leads to greater household responsibilities for women, which in turn widens of the income gap between spouses and creates a vicious cycle for women (Hersch and Stratton 1994). The more wives engage in home production, the less likely they would be able to return to labor market.

Beside micro-level household dynamics, the household labor division between spouses is also believed to be of relevance to the macro-level factors such as gender inequality, economic development, female labor-force participation, gender ideology (e.g., females are expected to do housework), and welfare regimes. Based on the 1994 International Social Survey in 22 industrialized countries, Fuwa (2004) found that macro-level factors are equally important in the dynamics of housework division between spouses. Specifically, macro-level factors set up the boundaries of micro-level influences. For example, for conservative countries like Germany (Esping-Andersen 1999), the general ideology against women to work dictates women's labor participation and also the micro-level household dynamics. On the other hands, the micro-level difference in household dynamics may allow for the variation in the division of labor in different families (Fuwa 2004).

2. The missing role of urban form

Although the theoretical underpinnings of the gender difference in daily activity patterns, originated from the economics and sociology realms, have progressed significantly, one may still wonder if other possible explanations exist that would arise beyond the original economic and

sociological domains. Notably, studies that relied on micro- and macro-level factors are often inadequate to account for the spatial variation of gender difference in travel behaviors. An extensive body of literature has demonstrated that land use may have an influence on travel patterns. Many scholars have presented evidence that design elements such as grid street patterns, mixed land uses, land use intensity as well as combinations of all three have been seen to both increase and decrease car trips, trip distances, modal split, and other travel patterns. Although the causal relationship between urban form and travel demands is still open for discussion, less is particularly known about how land use may interact with gender to influence travel outcomes. If land use does affect travel behaviors, does it affect men's and women's travel differently?

Decisions on travel often encounter many constraints in the reality. Tradeoffs made to cope with constraints may often go beyond the individual level and involve other household members. Gliebe and Koppelman (2002) suggest that in the cases of more extensive constraints, mandatory work activities are more frequently allocated to specific household members, especial men in families. Location and urban form would be relevant to the explanations of gender difference in travel patterns because different environments may provide different opportunities or imply different constraints for the task allocation within households. For example, Ettema et al. (2007) found that urban environments offer more opportunities for efficient trip chains, thereby allowing women to combine their maintenance tasks with work and leisure activities. These opportunities may also relax the spatial and temporal constraints faced by families and enable males' participation in maintenance activities. To the extent that most of the household-interaction studies do not consider the locations of activities, one of the central focuses of this

study is to detect the effect of urban form on the spatial variation of gender difference in daily activity pattern choices.

3. The complications of household interactions

Many studies on travel behaviors have recognized the gender difference in travel demands resulting from household interactions. For example, studies (Srinivasan and Bhat 2005, Golob 1997) showed that traditional gender roles continue to exist; women who are off the labor market are more likely to share a large burden of the household maintenance tasks. However, a consensus on the conceptual definition of intra-household interactions is still lacking. Analysts have not yet reached the consensus on what conditions household interactions are stimulated, how family members interact, and what results household interactions may lead to. The intricacy of household interactions was described in the statement of Alderman et al. (1995), as he put that "unlike all factories, a family consists of individuals who-motivated at times by altruism, at times by self-interest, and often by cajole, cooperate, threaten, help, argue, and support."

The mechanism of household interactions functioning due to either time availability or the relative powers of family members has been largely approximated by household lifecycles indirectly. Most research used socio-demographic profiles of households (such as the number of children, vehicle ownership, and other household lifecycle variables) to account for the result of gender difference in travel behaviors (Kostyniuk 1982, Scott D & Kanaroglou 2002, Ettema et al. 2006). For example, Sermons and Koppelman (2001) found evidence that the number of children in the household has a significant effect on the difference between male and female commuting distances within a household. However, household attributes such as the presence of children are only an indirect indication of family members' time constraints or relative power

relations; they cannot capture the varying nature of either time constraints or relative power relations. This approximation is particularly problematic when predicting travel demand.

Alternatively, other research has relied on certain travel decision outcomes, typically, division of work, shared ride, and joint activity engagement, to embody intra-household interactions. For example, researchers (Kostyniuk and Kitamura 1983, Chandraskharan and Goulias 1999) found that joint activity between adult heads of households is significantly affected by the presence of children and employment commitments. Couples without children are more likely to pursue joint out-of-home non-work activities than couples with children. However, it should be noted that joint trips are merely the outcomes of household interactions rather than household interaction mechanisms.

Whether household interactions were viewed as household lifecycle variables or the behavioral outcomes, the existing studies have masked the actual reasons that simulate household interactions and possibly determine the behavioral outcomes of household interactions: time availability or the relative power relation among household members. Before modeling household interactions, a clear conceptualization of household interactions is required, and studies on household interactions should strive to answer the following questions: *When do household interactions occur? How do family members interact? What factors govern household interaction outcomes?*

Why bother to discern the causal factors underlying the gender difference in travel behavior? As noted by Sinha et al. 2007, different factors may take distinct pathways towards

poverty reduction and economic growth (See Figure 2.1). Hence, knowing the most influential factors may better target the poverty reduction and economic growth strategies.

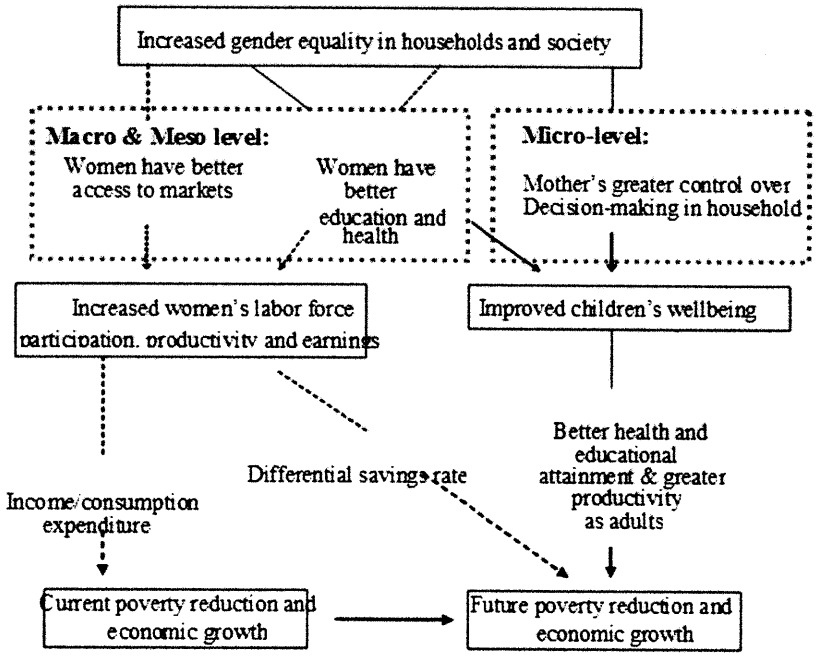


Figure 2.1 Pathways through which gender equality in households leads to poverty reduction (Source: adapted from Sinha 2007)

2.2 The operationalization of the causal inquiries on gender difference in travel behavior

Existing studies on household dynamics have been still confronted by a series of methodological deficiencies with deciphering and operationalizing causal relationship of gender difference in travel behavior and various contributing factors. Most of the discussion revolves around the relationship between travel behavioral outcomes and household interaction. The analytical efforts to model household interactions have raised several issues. These methodologies basically differ in two aspects: the units of decision makers and the units of analysis.

1. The units of decision makers

In general, studies that have explicitly accounted for intra-household interactions fall broadly into two categories featured by different decisions units: *unitary* models that treat households as the decision unit and *collective* models that treat individuals as decision units.

Unitary models assume that household members seek to maximize an aggregated family utility function subject to a common budget constraint. The models have been commonly based on the premise that households behave as if they are single individuals with homogenous preference, resources, and constraints (Alderman et al. 1995). However, more strong evidence has emerged against this premise. Particularly, models based on this premise fall short of explaining the causes to the gender differences in travel behavior in the first place. The different travel behaviors results of women and men in families usually require relaxing the premise to allow for individual differences in preferences, resources, and constraints among family members.

As a matter of fact, most models that use households as the decision making unit are a mix of unitary models and collective models. Particularly, several researchers described the way household members interact consisting of household-level activity allocation and a subsequent individual-level activity planning (Wen1999, Gliebe 2002, Gliebe 2005, Bradley 2005). Decisions that require household interactions such as the division of work and activity scheduling are thus given the priority over other decisions, and are mandated to be addressed in the first place. Although conceptually sound, unitary models have been subject to the criticism for its aggregated treatment of family decision makers: this type of models overstates the homogeneity among family members, while denying individuals' differences. Therefore, unitary models predict household behaviors can change only upon the changes of household attributes,

and they are not capable of distinguishing the varying impacts that policy initiatives have on family member. Even for the mixed models, the problems of unitary models also linger.

A range of alternative household models, collective models, incorporate a more complex understanding of how family decision-making occurs by allowing for differences in preferences, budget constraints and the control over resources (that is, bargaining powers). These collective models vary in different ways of integrating the heterogeneity among family members. Earlier research on collective models attempted to incorporate the difference in preferences of household members into the unitary model (Becker 1981). More recent collective models involve the simultaneous estimation of decision outcomes made by different family members via the structural equation models, seemingly unrelated models, and discrete choice models.

However, a more direct and disaggregated formulation of household interactions is based on game theory, where an agent's utility is allowed to depend on the action of other agents. The formal game-theoretic models assume that each household member has their own utility function in which decisions made by other household members are endogenously included: one's decisions will depend on how other family members react. Based on this formulation, the models have used either cooperative games or non-cooperative games to imitate the actual processes of household interactions. For example, Leuthold (1968), Browning (2000), and Chen and Woolley (2001) apply non-cooperative game theory to the decision-making of households.

Although many research studies have frequently employed game theory to analyze the interrelatedness of decisions, few can capture the situation when a household member has a disproportionate influence on other family members. Since most studies do not explicitly address these asymmetries in influences, this paper attempts to tackle this inadequacy.

Table 2.1 Unitary models vs. collective models

	Unitary models	Collective models
Model assumption	households behave as if they are single individuals	household members are different
Explanation of gender difference in travel behavior	household attributes or lifecycles	preferences, time constraints, and relative resources

2. *The unit of analysis of travel behaviors*

Another common problem with modeling of household interactions is the lack of an activity-based modeling framework. A fundamental conceptual problem with the traditional trip-based approach is the lack of dependence among trips. Trip-based models often assumed that there is no distinction between home-based trips made as a single-purposed tour and those made as a part of a multiple-purposed tour. On a household level, it is unlikely that households will determine the number of home-based trips and the number of non-home based trips separately. Rather, the needs of the households are likely to be translated into a collection of activities needed to carry out within a day and followed by joint decisions regarding how the stops and time schedules are optimally organized.

As a result, trip-based models can be instructive to capital-improvement policy instruments such as transit extensions. However, non-capital improvement measures such as carpooling and congestion pricing cannot be adequately represented (Deakin et al. 1993). The ability to model both individual activity behavior and interpersonal linkages between individuals is required for the evaluation of such TCM policies.

One notable behaviorally-based modeling approach is the activity-based approach. As opposed to the trip-based approach, the activity-based approach views travel as a derived demand that arises from the need to carry out activities distributed in space. Moreover, the approach is more conceptually appeal because it adopts a holistic framework to incorporate

natural time and spatial constraints and inter-tour (or inter-trip) dependencies. By emphasizing on activity participation and the patterns of travel behaviors, such an approach can inform the development of short-term TDM strategies through an improved understanding of how people modify their activity participation.

Although the activity-based approach has gained a growing recognition, the majority of studies on household interactions still used trip-based models and primarily focused on maintenance trips (Borgers et al. 2002, Gliebe 2002, Ettema et al. 2004, Fujii et al. 1999, Scott & Kanaroglou 2002, Srinivasan & Bhat 2004). One prominent problem with trip- (or tour-) based models is the interdependency between trips (or tours) is a direction outcome of household interactions. One cannot draw the inference of the existence of household interactions by only observing home-based or non-home-based trips. In addition, by focusing only on maintenance trips, these studies have bypassed the allocation of broad responsibilities, like work commitments and maintenance responsibilities, between family members. At the same time, the decisions on maintenance trips are often constrained by the time duration and the location of work commitments. Since maintenance and discretional activities are not executed on a daily basis, and they are often decided endogenously along with other decisions, the mere focus on maintenance and discretionary activities can lead to the selectivity bias. Therefore, without treating the daily activities as a whole, these models cannot incorporate all the constraints that families confront while they are making maintenance-related decisions.

Table 2.2 Trip-based models vs. activity-based models

	Trip-based models	Activity-based models
Shortcomings	lack of dependence among trips (e.g., spatial and temporal constraints) and inter-personal linkage.	
Policy implication	inform long-term TDM strategies	inform short-term TDM by indicating how people modify their activity participation. [7]

3. Hypotheses

Overall, the differentials in decisions on the daily activity pattern choices between women and men are possibly affected by a series of factors. Knowing factors driving or restricting activity participation is necessary to identify the roles played by household dynamics and land use characteristics. To recap, activity engagement is likely to be governed by various interrelated sets of factors and constraints (Arentze & Timmermans 2000, Hagerstrand 1970):

- Individual capabilities and preferences;
- **Micro-level family negotiations;**
- **Meso-level land use characteristics;**
- Macro-level socioeconomic influences: labor market dynamics, gender ideology, economic development, welfare regimes.

As a result, household interactions may not contribute to the activity pattern decisions if strong social influences, such as the gender ideology of the society, override intra-household dynamics. Similarly, the influence of spatial environment, e.g., built environment, on activity pattern decision may not be significant because families may probably have inherent preferences over the places they reside. To better identify the effect of each factor or constraint, all the possible intervening factors have to be controlled for. However, due to the data limitation, this paper is only able to test the factors of land use characteristics and household dynamics.

3.1 Decision variable: daily activity patterns

As reasoned above, activity-based models, proposed as an improvement of trip-based models, provide an efficient unit of analysis to detect the effects of household interactions and to understand the gender difference in travel behaviors. Daily activity patterns are defined as a sequence of activities carried out in a day. Bhat and Koppleman (1999) classified existing

activity-based studies into two groups based on the types of activity decisions under study: activity generation analysis and activity time-use analysis. *Activity time-use analysis* investigates the decisions on time allocation of daily activities, while *activity generation analysis* studies the decisions on the generation and scheduling of activities.

However, since there is no strong belief that household interactions would affect activity time allocation and activity generation decisions equally, it is still legitimate to examine the effects of household interactions on the two decisions separately. Given the fact that activity generation decisions are often made prior to time allocation decisions, it is essential to begin with investigating the relationship between household interactions and the decision on activity generation. By doing so, some travel decisions such as destination choices or vehicle availability that are of relevance to activity pattern generation are left out. Nonetheless, these decisions impose essential resource constraints on the decision of whether and how to carry out activities. Therefore, the omission of these decisions may leave the daily activity programs resulting from household interactions unfulfilled. Thus, by ignoring these decisions, the predictability of the model may be weakened.

Chapin (1971) proposed a motivational framework in which societal and individual motivations interact to shape the revealed activity participation patterns. Since motivations can be easily interpreted as the purposes of activities, activity generation is thus defined as the activity purposes. According to Maslow 1970, individual and familial travel motivations are rather hierarchical, and they span from deficiency and basic living need at the lower end to the growth needs at the top end. The home-to-work commute often serves to meet the basic living needs, and it structures other trips made during the day (2006). Note that maintenance activities are neither an obligatory task like home-to-work commute nor an optional task like leisure.

Particularly, although maintenance activities are performed to satisfy the basic living needs, it can be done by different family members and subject to household interaction constraints. The decisions on house-sustaining may be more subject to the activity and travel decisions made by dominant decision-makers in a family. According to this rational, activities executed within a day are divided into four types: in-home activities, subsistence activities, maintenance activities that serve other family members (house-sustaining), and maintenance and discretionary activities on behalf of oneself (individual maintenance):

- **In-home activity** (including working at home)
- **Out-of-home activities:**
    - **Subsistence (W)** such as work, school, and business.
    - **House sustaining (F)** such as picking up\dropping off, shopping.
    - **Leisure (I)** such as visiting friends, recreation, and others.

However, it should be noted that this classification provides only a crude basis for identifying the motivation behind each activity. Shopping activities, for example, can be executed for fun, for house-sustaining tasks, or for leisure. However, without surveying for the real intention behind shopping activities, imprecision always exists. Moreover, note that for different family members, the motivation of carrying out the same activity is not exactly the same. For young children, spending time at playgrounds is for enjoying leisure activities, while for parents who stand beside the playgrounds to watch out for their children, the time they spend is for house-sustaining. Moreover, note that not all family and individual maintenance tasks such as shopping or leisure activities are decided on daily basis. Nonetheless, since a week-long survey is still lacking, this selectivity-bias problem is difficult to avoid in this study.

Ultimately, the decision variable, each family individual's daily activity generation, is constructed by concatenating the above activity types together. Since scheduling is not within the scope of this paper, the same combination of activities ordered in different ways will still be counted as one. The complete set of the decision variables for this study is listed as below:

Table 3.1 Eight types of daily activity patterns

Index	Daily activity pattern	Acronym
1	None	NONE
2	Work or school only	W
3	Work + house-sustaining	WF
4	Work + house-sustaining + individual maintenance	WFI
5	House-sustaining only	F
6	House-sustaining + individual maintenance	FI
7	Individual maintenance only	I
8	Work + individual maintenance	WI

Although the correlations among the eight activity patterns are inevitable, in this paper, the eight alternatives are treated as independent.

3.2 Micro-level factor: Household interactions

Household interactions, a type of social interactions characterized by strongest social ties, arise when individual family members affect each other's decisions, preferences, expectations, and choice sets directly rather than indirectly through markets. Given the data limitation, most research focuses on understanding how *decisions* are affected by other family members. However, it is noteworthy that some seemingly-joint decisions such as task allocation are not made based on household interactions. This decision outcome is attributed to individual *heterogeneity*, where household members may simply have an intrinsic preference over their choices. As a result, family members are consensual on the decisions they make, as opposed to the previous case where family members reach disagreements and have to resort to household

interactions to reconcile (this process is known as accommodative decision making). For example, wives may inherently prefer the handling of money and keeping accounts; their decisions to undertake this task may have nothing to do with how the other family members react. Making this distinction between household interactions and taste heterogeneity is crucial because the two may lead to the same behavioral outcomes, although the underlying driving forces are different. Moreover, compared to taste heterogeneity, household interactions often coexist with disagreements. Therefore, to better understand household interactions, the effect of heterogeneity must be distinguished from that of household interactions. While research evidence is limited, some research (Davis, Sprey 1969, Weick 1971) suggests that families quite often encounter disagreements. Therefore, the following will restrict the focus to household interactions.

Among the studies on household interactions, some have noted that household members do not involve in the household interactions to an equal degree. Different family members may have relatively different influences over others with regard to different decisions, due to varying preferences and abilities to pursue their interests. Therefore, within a household, some decisions are more jointly decided than the other. For example, major items of consumption such as food, shelter, and transportation are jointly determined. At the same time, one household member may be more influential than the others on certain decisions (See Figure 3.1). Realizing the nature of influences among household members with regard to travel and activity decisions is central to answer the two questions outlined above: How do household members interact? What factors govern household interactions outcomes?

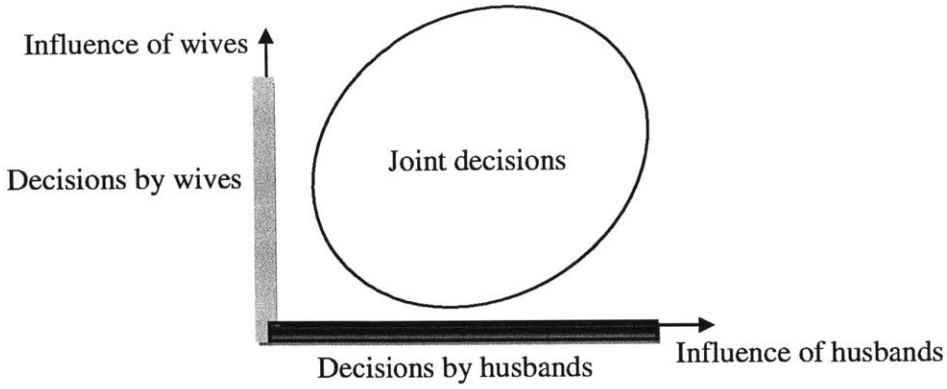


Figure 3.1The individual and joint decisions made by spouses

The influence that one family member has on the other can be more formally known as bargaining power[2]. Defined by Svejnar (1986), bargaining power is an "exogenously determined force that affects positively the decision maker' ability to realize a gain over a disagreement outcome." Strictly speaking, bargaining powers of household individuals are determined exogenously by: (1) control over resources such as assets, (2) mobilization of interpersonal networks, and (3) basic attitudinal attributes (Quisumbing 2006).

Household interactions on travel decision-making are quite likely to be observed in families. First, travel and activity decisions are sometimes motivated to fulfill familial accessibility demands. Household interactions are likely to occur to resolve any disagreement that may arise from realizing these accessibility demands. Second, carrying out daily travel and activity needs may be hindered by various constraints (e.g., time limitation or car availability). Tradeoffs made to cope with constraints would sometimes go beyond the individual level and involve other household members. The resulting equal or unequal distributions of benefits among family members are largely determined by the influences of different family members

[2] Here, influences and bargaining powers are used interchangeably.

exerting on one another: the powerful household member will get the bulk of the benefits (and the least costs).

This study advances the past arguments about daily activity patterns between wives and husbands by summarizing that both human capital and wages along with other possible factors (See Section 3.2) define the bargaining powers of family members. The family member with the most bargaining powers may negotiate their way out of certain decisions like undertaking house-sustaining work. Since the bargaining power is an abstract construct that deters direct measurements or observations, it has to be quantified by decomposing it into different observable and measurable indicators like human capital or wages. However, with the lack of the data to measure each component of bargaining powers, this study avoids the process of actually quantifying the relative bargaining power by assuming that a certain pattern of bargaining power distribution prevails in families in Santiago de Chile.

Although it is less arguable that young children benefit the most from this bargain and redistribution process due to their limited mobility, it is often not certain how the bargaining powers distribute between husbands and wives for travel and activity decision-making. In this paper, I hypothesize that wives tend to play the most accommodating role in decisions on transportation and activities due to their relatively-weak position in bargaining games.

Note that this hypothesis can be subject to questioning. First, one complication with dealing with the bargaining power distribution among family members is that this bargaining power relation within households often exhibits great variability that it cannot be easily generalized across families or decisions. Second, it has to be acknowledged that the participation of women with children in the labor force has increased in past decades. Against this backdrop, wives and mothers have been gaining growing bargaining powers, and they are not always

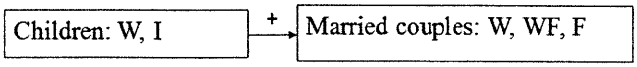
playing an accommodating role in households. Third, mixed household interaction strategies that are context-dependent and path-dependent are not uncommon in reality. As contended by Davis (1976) wives may "give in some encounters so that she can get her way in a later decision."

However, since an exhaustive list of intra-household interaction processes with regard to travel and activity decisions is still lacking and different interaction processes may cause the same behavior outcomes, it is still natural to start with one household interaction strategy to develop a prototype model and later to extend the model to capture the heterogeneity of family household interactions. Moreover, this relatively simple hypothesis helps to reduce numerous household interactions occurred in reality, thereby facilitating my analysis. Particularly, the region that this study focuses on, Santiago de Chile, is still characterized by a low female labor-force participation rate (less than 39 percent), which situates the country almost at the bottom of all the Latin America countries. As Chilean women become more educated, they are expected to have a larger presence in labor market. Yet, the high education attainment of Chilean women has not generated higher ratios of female labor force participation, as expected. On the contrary, mothers are still supposed to be the principal caregivers in families (World Bank 2007).

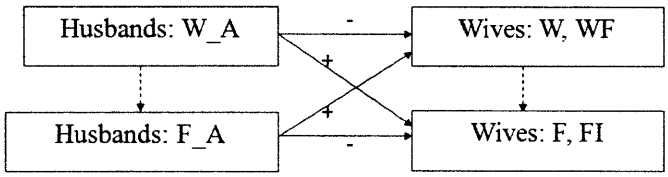
More broadly, the gender difference in daily activity patterns, are concerned with the two issues: the demand for the home-produced services by children, and the division of responsibilities between spouses:

Hypothesis 1.a: The demands for work and house-sustaining: Children's school and discretional activities (W and I activity patterns) would be translated to more demands for work and house-sustaining activities (that is, W, WF and F activity patterns) from parents. This is because for young children need to be escorted by family adults to ease their restricted mobility.

Moreover, more kids in a family mean more mouths to feed and therefore increase the bread-earning burdens.



Hypothesis 1.b: The division of responsibilities: Husbands' engagement in the work activities (including W, WI, WF, and WFI) tends to influence wives' participation in work activities negatively and wives' participation in house-serving activities positively. Therefore, this hypothesis aims at capturing a substitution relationship between women's and men's daily activities, where wives tend to maintain a traditional childcare and housekeeping role.



Note: W_A includes W, WI, WF, WFI. F_A includes F, WF, FI, WFI.

Figure 3.2 Hypotheses of the interrelatedness of household travel and activity decisions

3.3 Meso-level factors: Built environment

Although studies that focused on the relationship between built environment (BE) and transportation (that is, travel behavior = f (BE)) have made significant progress in the past decades, these studies have been primarily confined to the individual level (Levinson 1999, Schwanen 2004). This paper attempts to examine to what extent household interaction outcomes vary by households' residential built environments.

The way that the built environment affects travel behaviors is often confounded by cost (and benefit) exchanges among household members due to the negotiation among them. Moreover, the relaxation of the spatial constraints confronted by families may trigger family

members to reinvest the saved travel time to help other family members; for example, husbands may increase their participation in maintenance activities in the face of mixed land use development. Consequently, land use and urban design elements may affect men's and women's travel differently. Evidence has shown that urban form seems to be more important for women than for men when activity durations are concerned. This may reflect the fact that women tend to be responsible for trip-chaining work and housekeeping tasks to a greater degree; they are under larger time pressure and have to make more tradeoffs between work and families (Ettma et al. 2007).

Hypothesis 2: Given the past empirical evidence, if the availability of spatial opportunities (to employment and to amenities) can be relaxed, it may lead to a less restricted allocation of tasks between spouses. Therefore, I hypothesize that males are more likely to engage in maintenance activities, if households reside in urban center and have a neighborhood characterized by mixed land use, grid street network and high residential density.

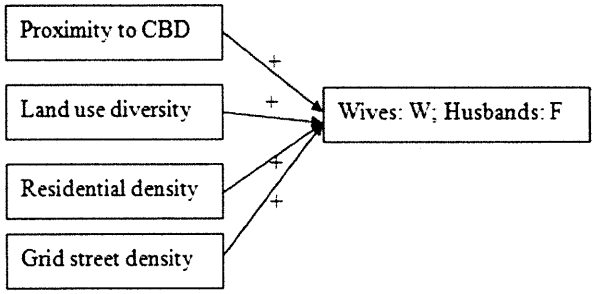


Figure 3.3 Hypotheses of the effects of urban form on household travel and activity decisions

However, how built environment and household interactions jointly (travel behavior = f (BE, household interactions)) influence activity pattern choices still demands to be examined with great discretion. The primary concern is the issue of self-selection. Households with wives taking on the primary portion of house-sustaining work may choose to live in areas where this is possible, e.g., suburban areas. For example, as demonstrated by Kitamura et al. (1997), the

choice of certain travel behaviors relies so strongly on ones' attitudes and preferences that higher residential densities or land use diversity cannot alter travel behaviors significantly. This empirical finding underlines the core of the issue: do neighborhood characteristics influence behavior or do living habits and preferences influence the choice of neighborhoods?

This pattern caused by self-selection can be further reinforced by car access. Particularly, if a second car is available to the households, both partners are less dependent on the surroundings of their residence places and more likely to reside on suburb or a low-density, single-use neighborhood. Thus, the impact of urban form may be reduced substantially. However, adding car access into the study would further aggravate the issue of self-selection, since it is unknown if car ownership leads to a greater degree of household labor specialization or vice versa. Since in this study, either attitudinal surveys or time-series data are lacking, it should be cautious that alternative explanations to the spatial variation in activity pattern choices for residents in Santiago still exist.

3.4 Household attributes or lifecycles

One of the important variables that trigger the changes in travel behaviors is family life cycles in which different stages of family life cycles are featured by different travel behaviors. As family lifecycles are often represented by household attributes, they are the most common variables used in household interaction literature, particularly the unitary models, to proxy for household dynamics. Specifically, Townsend (1987) found that working females made fewer maintenance trips than non-working females. The presence of children reflects more on females. Maintenance trips are greater for mothers and lower for fathers when compared to their childless counterparts. The employment status of both adults has been found to influence whether a joint activity originated from home or out of home (Kostyniuk & Kitamura 1983).

Although these studies have provided insights into the nature of household interactions, their primary focus on households in the U.S. context has overlooked other household interaction possibilities that emerge from a different cultural context. Since household attributes are culture-specific, the influences they have on daily activity pattern decisions are better to be investigated in conjunction with the cultural context where the data set is gleaned.

Building on ample empirical results from previous studies on household interactions, a few hypotheses about the effects of household attributes on household interactions are contemplated. Specifically, the larger size of households may require a higher degree of synchronization among parents and children, and therefore increase both the bread-winning and house-sustaining requirements. Similarly, the presence of grandparents may also increase housekeeping burdens of parents. Moreover, given the fact that low-income families often have low employment, they may be more likely to have in-home activities or have house-sustaining activities done on their own. By contrast, high-income families are more likely to outsource their in-home and house-sustaining activities (such as cooking or babysitting) to others outside their families. As a result, they may be more likely to undertake fewer house-sustaining activities and more leisure activities within a day.

4 Model Specifications

To test the foregoing hypotheses, the methodological obstacle to model household interactions has to be overcome first. Here, a collective model is developed in which decision outcomes are endogenously included to represent the influence that some family decision makers have on the others. Obviously, this collective model is based on the premise that family members are endowed with heterogeneous degrees of bargaining powers. Actually, as illustrated later in this section, the hypothesis of the dominance of influences exerted by husbands helps avoiding the onerous process to estimate a simultaneous discrete choice model. In this section, I first begin with the basics of multinomial logit models and discrete game models and then demonstrate the development of the collective model.

4.1 Multinomial logit model

Owing to recent developments in psychological and econometric research, researchers are able to imitate the subjective decision making of individual travelers. Typically, they adopt a disaggregated approach, formally known as random utility models. In these models, each alternative (whether a single decision or a hierarchy of decisions) is defined by its utility perceived by travelers. Given the fact that human behavior is inherently probabilistic, the utility of each alternative is also associated with a random disturbance. In mathematical form, the utility U can be decomposed into a deterministic term V and a random disturbance.

$$U = V + \varepsilon .$$

Among random utility models, the multinomial logit (MNL) model has been the most widely used structure for modeling discrete choices in travel behavior analysis. In MNL, the random components of the utilities follow the extreme-value (or Gumbel) distribution

(McFadden, 1973), and the model allows for the choice set to include more than two alternatives. If there are C alternatives, and each has K attributes, the utility of alternative j for individual i can be written as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum_{k=K} \beta_k x_{ik} + \varepsilon_{ij}, j \in C$$

where β_k denotes the coefficient of attribute x_{ik}.

The probability for individual i to choose alternative j is:

$$P_i(j) = prob(U_{ij} > \max_{t \in C, t \neq i}(U_{it})) = \frac{e^{\mu U_{ij}}}{\sum_{j \in C} e^{\mu U_{ij}}},$$

where μ is the scale parameter.

Notably, an unbiased estimation of MNL model must ensure that the error variance-covariance structure of the alternatives is identical across individuals (i.e., an assumption of error variance-covariance homogeneity). In other words, the random terms of the different alternatives in the MNL model are assumed to be independent and identically distributed across alternatives and individuals (also known as Independence from Irrelevant Alternatives Property, i.e., IIA Property).

Note that the failure to incorporate household interactions into travel demand models often violates the IIA Property. Intra-household interactions entail that the choices of travel and activity patterns are correlated among family members. For example, Golob and McNally (1996) found a strong correlation between persons if they are jointly engaged in maintenance and discretionary activities. If this correlation among decisions is not integrated in the model's exogenous variables, it will be included in the error disturbance:

$$\varepsilon_{ij} = \text{cov}(i, m) + \delta_{ij}$$

where $\text{cov}(i,m)$ is the correlation of the decision made by individual i and the decision made by individual m, and δ_{ij} is the portion of the error term that follows the IIA property.

Since the error disturbance ε_{ij} is correlated with ε_{mj}, one solution to remedy the problem is explicitly describing the term $\text{cov}(i,m)$ in the deterministic utility:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \sum_{k=K} \beta_k x_{ik} + \text{cov}(i,m) + \delta_{ij}, j \in C.$$

Therefore, the crux of the problem becomes how to specify $\text{cov}(i,m)$ to reflect the dominant interaction pattern between family members.

4.2 Discrete game models

Since game theory is often a sound analytical framework for modeling interrelated decisions, it provides a solution to the above question. Although game-theoretic models have been commonly used for continuous choices or strategies, they have been gradually extended to model discrete decisions. Researchers have pointed out that discrete game models are a generalization of discrete choice models (Bajari et al. 2008). Although the two models share many analogies, an important difference between the two is discrete game models include interrelated decision-makings among people. In the discrete game models, the presence of simultaneity among decisions complicates the case. A generic feature of discrete game models is that there are often multiple equilibrium results.

The following illustrate a normal-form discrete game model. For simplicity, consider two agents, family member 1 and family member 2, who choose an action (supposedly, alternative j) simultaneously. The utility payoff (or payoff) of the alternative each agent chooses depends on

how the other agent reacts. Table 1 provides an example of the payoff matrix for family member 1.

Table 4.1The payoff matrix of family member 1 to choose alternative j

	$y_{2j}=0$	$y_{2j}=1$
$y_{1j}=0$	c_1	c_1
$y_{1j}=1$	$c_1+Bx_{1j}+\delta_{1j}$	$c_1+Bx_{1j}+\gamma_1 y_{2j}+\delta_{1j}$

In Table 1, c_1 denotes the utility that family member 1 has if he does not choose the alternative ($y_{1j}=0$). On the other hand, if family member 1 chooses the alternative ($y_{1j}=1$), his utility will depend on the decision made by family member 2, $\gamma_1 y_{2j}$. A simple calculation shows if household member 1 chooses the alternative, he will have to maximize the following utility function:

$$U_1 = c_1 + Bx_{1j} + \gamma_1 y_{2j} + \delta_{1j}.$$

Similarly, for family member 2, he also maximizes his utility function:

$$U_2 = c_2 + Bx_{2j} + \gamma_2 y_{1j} + \delta_{2j}.$$

Since normal-form games assume simultaneous moves, both persons must maximize their utility at the same time. Therefore, the discrete game model can be written as:

$$\begin{cases} U_{1j} = c_1 + Bx_{1j} + \gamma_1 y_{2j} + \delta_{ij} \\ U_{2j} = c_2 + Bx_{2j} + \gamma_2 y_{1j} + \delta_{2j} \end{cases}$$

where $P_{1j} = \dfrac{e^{c_1+Bx_{1j}+\gamma_1 y_{2j}+\delta_{1j}}}{\sum e^{c_t+Bx_{ij}+\gamma_t y_{ij}+\delta_{ij}}}$ and $P_{2j} = \dfrac{e^{c_2+Bx_{2j}+\gamma_1 y_{1j}+\delta_{2j}}}{\sum e^{c_t+Bx_{ij}+\gamma_t y_{ij}+\delta_{ij}}}$.

This model resembles the above multinomial logit model in a way that $\mathrm{cov}(i,m)$ in the multinomial logit model is specified as $\gamma_m y_{mj}$ and $\gamma_i y_{ij}$. Nonetheless, compared with the discrete choice models, including y_{2j} and y_{1j} adds complexity to the discrete game model

because y_{2j} and y_{1j} are simultaneously determined. The simple application of random utility methods is problematic.

4.3 A collective model for household interactions

Simpler than the above applications of game theory, this study assumes that husbands in households have a relatively greater influence over wives on travel and activity decisions. To represent the strong bargaining power of men, the coherency condition ($\gamma_1\gamma_2 = 0$) enforcing a one-way interaction among family members is imposed. Suppose family member 2 has a dominant influence, the coherency condition entails $\gamma_1 = 1$ and $\gamma_2 = 0$. After imposing the condition to the above equation, the simultaneity issue is eliminated, and the model is reduced to a regular multinomial logit model:

$$\begin{cases} U_{1j} = c_1 + Bx_{1j} + \gamma_1 y_{2j} + \delta_{ij} \\ U_{2j} = c_2 + Bx_{2j} + \delta_{2j} \end{cases},$$

where $P_{1j} = \dfrac{e^{c_1 + Bx_{1j} + \gamma_1 y_{2j} + \delta_{1j}}}{\sum e^{c_t + Bx_{ij} + \gamma_t y_{ij} + \delta_{ij}}}$ and $P_{2j} = \dfrac{e^{c_2 + Bx_{2j} + \delta_{2j}}}{\sum e^{c_t + Bx_{ij} + \delta_{ij}}}$.

However, different from unitary models that also employ MNL specifications, this collective model includes a $\gamma_1 y_{2j}$ term that is able to distinguish different bargaining powers between spouses. As a consequence, the collective model does not seek to maximize an aggregated family utility function but rather acknowledges the fact that family members behave rather differently and follow the power relation within a household.

Unlike the interactions among firms, household interactions also exhibit other uniqueness, one of which is the utility of family member 1 is not only affected by the same decision by other family members, but also influenced by a different decision made by the rest of

family members. For example, work commitments often require at least one person to assume house-sustaining responsibilities. Therefore, a model to capture this interrelatedness of different decisions (alternative j and q) can be similarly formulated as:

$$\begin{cases} U_{1q} = c_1 + Bx_{1q} + \gamma_1 y_{2q} + \delta_{ij} \\ U_{2j} = c_2 + Bx_{2j} + \delta_{2j} \end{cases},$$

where $P_{1j} = \dfrac{e^{c_1 + Bx_{1j} + \gamma_1 y_{2j} + \delta_{1j}}}{\sum e^{c_t + Bx_{tj} + \gamma_t y_{tj} + \delta_{tj}}}$. Therefore, the utility of family member 1 selecting alternative q depends on whether family member 2 chooses alternative j.

5 Data Description

To test the conceptual and technical model, Santiago de Chile is used as the pilot area. A sweeping wave of urbanization has been under way in Chile with the bulk of the population moving into the urban areas. Accordingly, Santiago has expanded quickly in the past decades; and it has struggled with many problems associated with rapid urbanization, such as to accommodate the influx of incoming residents and to provide adequate services and infrastructure. Therefore, this fast pace of urbanization has not only added strains to urban housing projects, transportation system, but also has stressed the ecology system and caused severe air pollution.

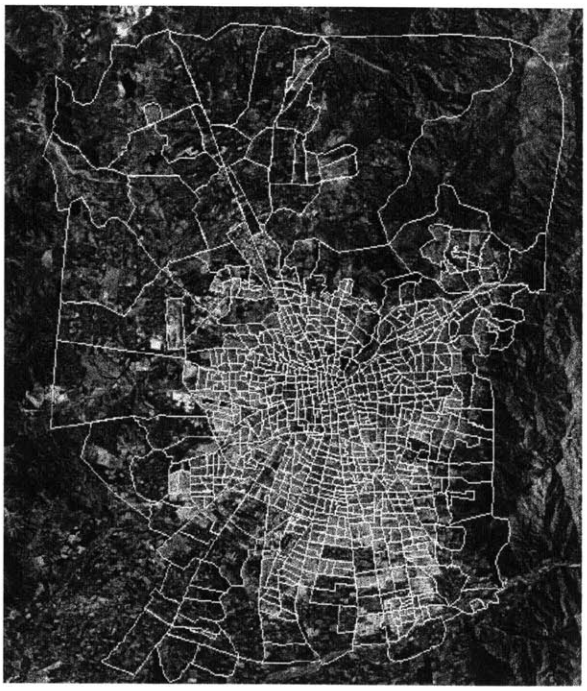


Figure 5.1The satellite image of the city and its TAZ boundaries

In the midst of the rapid urbanization, the city is also undergoing considerable socioeconomic transformations. Over the past decades, the city has made considerable strides in fostering economy along with closing the income gaps. Nowadays, women in Chile have increasingly gained equal opportunities to men in term of education, health, and legal rights. Yet,

these achievements have still been greatly stalled by the gender inequality problem in Chile. For example, the country still have a low female labor-force participation rate (less than 39 percent), which situates the country at the bottom of all the Latin America countries. According to the traditional values and attitudes, mothers are still supposed to be the principal caregivers in families. This situation is further aggravated by the limited childcare options available, especially for the poor (World Bank 2007). The city is critically posited to overcome its gender inequality problem that is believed to impede the city's effort to achieve economic development and poverty reduction (World Bank 2007). At the same time, the socioeconomic transformation has posed a great challenge to the planning of the city's transportation and land use planning system. How the tackling of the gender inequality in Santiago will in turn affect land use and transportation planning is worth investigations.

This research utilizes 2001 mobility survey data of Santiago, Chile, a travel diary collected by the national transport planning authorities (SECTRA). The survey contains a random sample of 15,000 households, among which 9, 040 households were surveyed during non-summer weekdays.

5.1 Household and individual attributes

In addition to all trips taken by all household members, the survey also contains information on household income, income levels and other household attribute information. Although the number of children, household sizes and other aggregated household backgrounds are not directly provided in the survey, it can be derived.

This paper analyzes the individual daily activity patterns of married partners with ages under 55 years, and children are not modeled as one of the decision makers. Note that in this

paper, not all the households in the survey are of interest to the analysis. This study follows the precedent tradition to focus on the household interaction processes in *nuclear families* (families that have married partners with at least one of them being a worker). By doing so, the study can circumvent the modeling of household lifecycles that confound the analysis on household interactions. This treatment guarantees a relatively homogenous decision unit across the data set by omitting different household interactions emerging from single-parent families, retired households, and other household types.

After screening out the households that do not meet the criterion, the final estimation set includes a sample of 5,150 households and 10,300 individuals (counting only wives and husbands). A few descriptive statistics are summarized for the households in the estimation set (See Table 5.1). It is found that nuclear households in Santiago exhibit unique characteristics that are distinct from households in the U.S. First, the average household size is generally larger in Santiago. Compared to an average three-person family[3] (average family size = 3.19) in the U.S. (U.S. Census 2010), the average household size in Santiago, Chile is about five persons, three of which are children. Another peculiarity with families in Santiago, Chile is approximately 21% of families in Santiago that have three generations living under the same roof. Presumably, the unique family-structure characteristics of the city along with other culture-specific factors may nourish travel and activity behaviors of local Santiago residents that are different from the U.S. residents. Instead of being omitting, these culture-specific attributes of families are incorporated in the model to allow for the cultural sensitivity of the model.

Table 5.1The descriptive statistics of household attribute variables

Variable Name	Description	Total

[3] According to the U.S. census, a family refers to a group of two or more people who reside together and who are related by birth, marriage, or adoption, which is similar to my definition of the estimation group in Santiago, Chile.

		HHs
B_HSIZEOVER5	Dummy: whether the household size is larger than 5	1089
BChild6	Dummy: whether the household has children under 6 years old	1393
Bchild16	Dummy: whether the household has children over 6 years old and under 17 years old	2669
B_3G	Dummy: whether the household has three generations	1419
B_HIGHINC	Dummy: whether the household is a high-income family	846
B_LOWINC	Dummy: whether the household is a low-income family	1816

5.2 The measurements of urban form

The land use data were drawn from 2001 national tax records and business and land use permits. The analysis investigates four aspects of built environment around the residences of the households: distances to the central business center (CBD), gross residential densities (DENSITY), land use mix (DI), and road densities (RDDEN). These four variables are measured on a traffic analysis zone (TAZ) level (with 770 TAZs).

The city-wide gross density of the city is about 72 persons per hector, which puts Santiago among the high-density cities around the world. It is denser than cities in developed countries including cities in the U.S. and Europe but is still not comparable to cities in Asia. With the expectation that the population of the city will likely grow rapidly in the future, as in other cities of the developing world, the rank of Santiago will probably go up sooner or later. As shown from the density map, the most populous areas of the city are the central business district and several pockets of highly-dense suburban neighborhoods.

The degree of land use mix is measured by using the approach proposed by Rajamani et al. (2003)[4]. As shown by the map, the diversity index peaks at the center and gradually

[4] $DI = 1 - \left[\frac{\left|\frac{r}{T} - \frac{1}{6}\right| + \left|\frac{c}{T} - \frac{1}{6}\right| + \left|\frac{h}{T} - \frac{1}{6}\right| + \left|\frac{o}{T} - \frac{1}{6}\right| + \left|\frac{p}{T} - \frac{1}{6}\right| + \left|\frac{s}{T} - \frac{1}{6}\right|}{\frac{5}{3}} \right]$, where DI=diversity index, r = residential areas, c = commercial areas, h = health/community service areas, o = office areas, p =

decreases toward the outer city. However, it climbs up again as it reaches the periphery of the city; this odd pattern may be resulted from the large-sized TAZ on the city's boundary. Overall, land use is most diverse at the heart of the city, while it turns more isolated as going outward.

Lastly, the street configuration of the city is measured by the number of four-way intersections per street length. As shown in the map, the neighborhoods well-connected by grid streets are also the ones that are densely populated, indicating relatively desirable road connectivity in the city.

Table 5.2 The descriptive statistics of built environment variables

Variable Name	Description	Mean	Maximum
CBD	Distances to the central business center	8.6 kilometers	28.6 kilometers
DENSITY	Gross residential densities	72 persons per hector	400 persons per hector
DI	Land use mix (diversity index: between 0 and 1)	0.17	0.77
RDDEN	Road densities (# of 4-way intersection per kilometer road length)	1.6	4.8

public administration areas, s = social services areas, and $T = r + c + h + o + p + s$. A value of 0 for this index means that the land in the area has a single use and a value of 1 indicates perfect mixing.

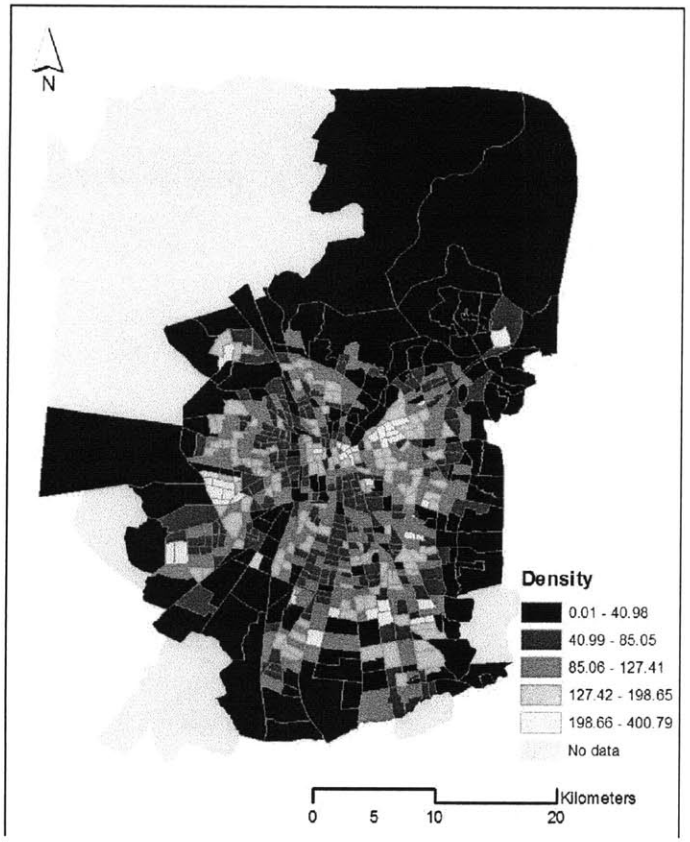


Figure 5.2a Residential density (persons per hector)

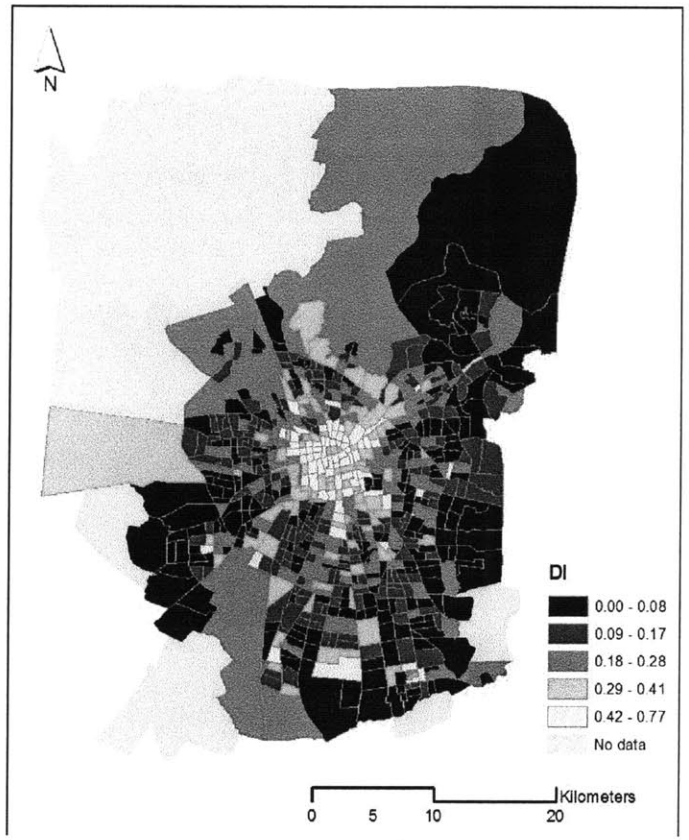


Figure 5.2b Diversity index (1:diverse; 0: single use)

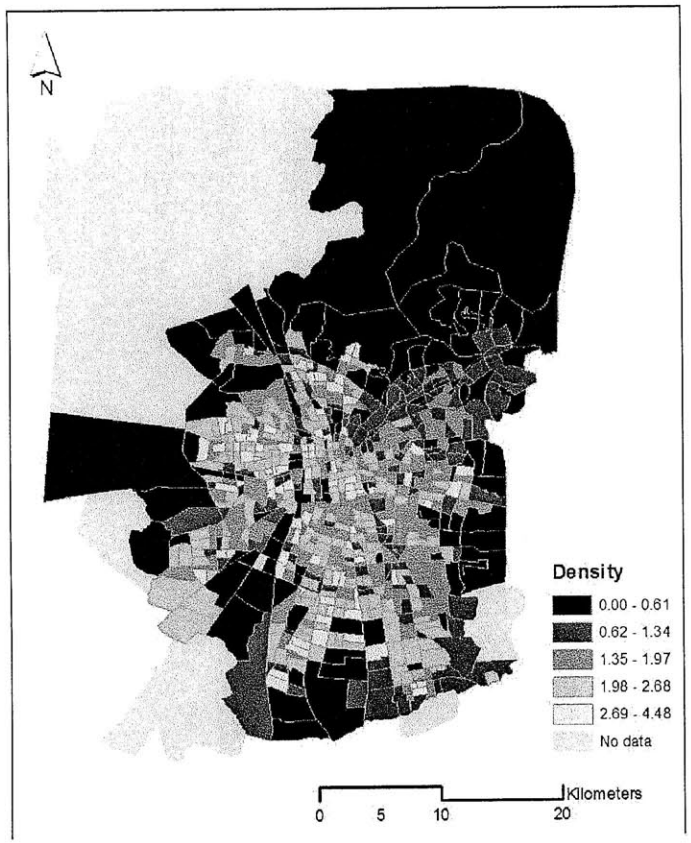


Figure 5.2c Road density (# of 4-way intersection per road length)

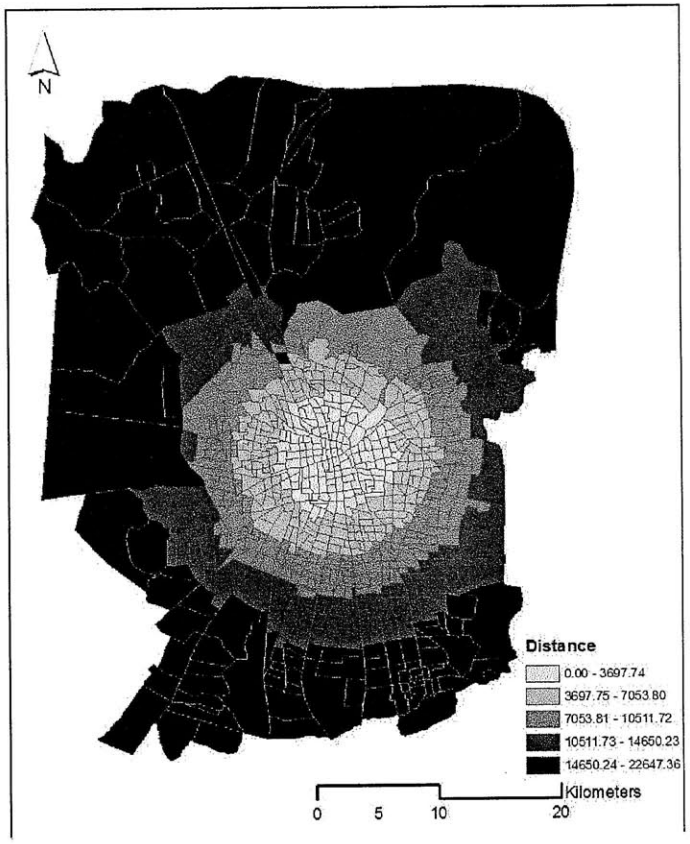


Figure 5.2d Distance to CBD (in meters)

5.3 Daily activity patterns

Essentially, in the model, the variable of daily activity patterns plays two roles: it is not only the decision outcomes but also the input variable to reflect the interrelatedness of decisions between spouses. Only the decision outcomes of parents are analyzed as dependent variables; the daily activity patterns of children are merely treated as input variables.

1. Activity patterns as decision outcomes

Although the mobility survey was not designed as an activity survey per se, a classification of thirteen trip purposes was used, most of which can be translated into activity purposes with few modifications. Furthermore, these activity purposes are aggregated based on a broad-sense typology of activities proposed in the earlier section:

- **Subsistence:** work, school, and business.
- **House-sustaining**: pickup\drop-off, shopping, paperwork
- **Leisure**: for health, visit, eat, pickup\drop-off something, recreation, others.

As pointed out earlier, for different family members, the motivation of carrying out the same activity is not exactly the same. For young children, spending time at playgrounds may be for leisure activities, while for parents who accompany to watch out for the children, the time they spend is for house-sustaining. Since the travel survey has made this distinction (where the trips made by parents to accompany children joining in outdoor activities are flagged as escorting trips), no further data processing is needed. Although young children are also likely to watch over each other and accompany each other to schools, this case is rather rare in relative to the incidences of parents' escorting children to schools. Therefore, it is not considered by the survey. Ultimately, the variable of daily activity patterns is constructed for each individual in by

concatenating the activity types in sequence. The daily activity pattern of "spending time at home" (NONE) is inferred from the data set if an individual does not engage in any out-of-home activities throughout a day. In the end, eight kinds of activity patterns are identified. A new dataset is then created in which each record represents an individual's daily activity pattern. Table 5.3 and Figure 5.3 summarize and then visualize the frequencies of individuals' choosing each activity pattern.

Table 5.3 Frequencies of the daily activity and travel patterns of different family members

	Daily activity pattern	**Acronym**	**# of Wives**	**# of Husbands**	**Total**	**Percentage of female spouse with the same activity pattern**
1	None	NONE	752	560	1243	57%
2	Work or school only	W	863	2288	3002	25%
3	Work + house-sustaining	WF	475	856	1281	35%
4	Work + house-sustaining + individual maintenance	WFI	124	271	381	31%
5	House-sustaining only	F	1887	629	2406	77%
6	House-sustaining + individual maintenance	FI	793	269	1028	76%
7	Individual maintenance only	I	367	172	518	69%
8	Work + individual maintenance	WI	125	339	442	25%
	Total		5150	5150		

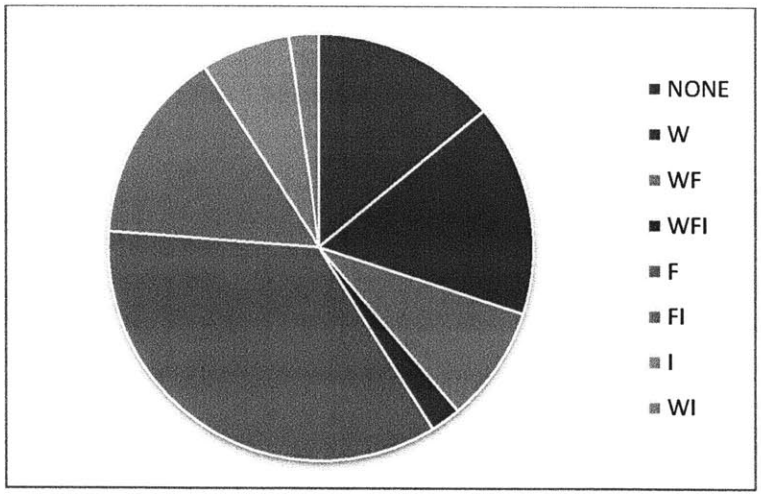


Figure 5.3a Frequencies of the daily activity patterns of wives

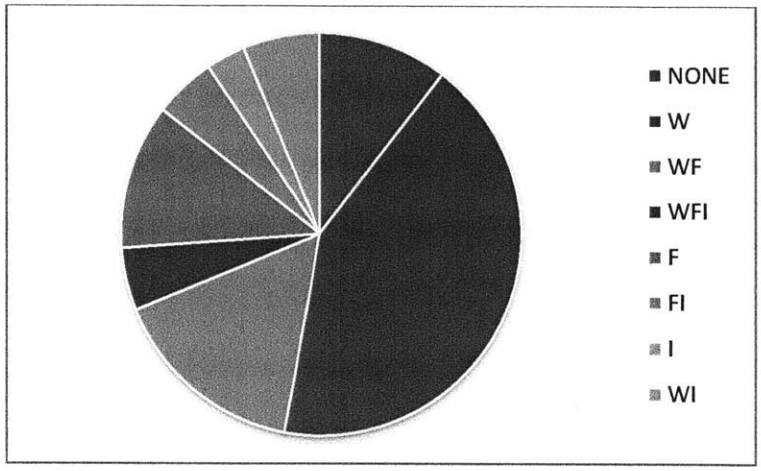


Figure 5.3b Frequencies of the daily activity patterns of husbands

2. *Aggregated activity patterns as independent variables*

Given the multi-dimensional nature of the eight activity patterns (most activity patterns actually involve more than one decision), for conceptual and modeling convenience, the eight activity patterns are collapsed into one dimension according to the type of activity that each activity pattern contains (see Table 5.4). These four aggregated activity types are used as independent variables to calibrate the interdependency between the activity type by one family member and the activity pattern by the other family member.

Table 5.4 Aggregated activity types for one individual's daily patterns

Aggregated daily activity pattern	# of wives	# of husbands	# of young children (<17 years old)
None	710	533	n/a
W_A (W+WF+WI+WFI)	1432	3674	4226
F_A (F+WF+FI+WFI)	3214	1882	n/a
I_A (I+WI+FI+WFI)	1373	996	2478

Unlike the daily activity patterns as dependent variables, when treating them as independent variables, the decisions of school and leisure activities by young children are also considered to allow for the testing of the conditionality of parents' decisions on children's activity patterns. For the case of children's staying at home, it is not summarized because this choice is less likely to prompt the out-of-home activities by parents. Although young children are also likely to participate in house-sustaining activities, they are often "luggage" and not the ones who actually initiate the activities.

In summary, as revealed from Figure 5.3 and Table 5.4, it is evident that work and house-sustaining trips constitute the vast majority of the out-of-home activities, while leisure activities are rare and infrequent. More importantly, wives seem to be predominately engaged in house-sustaining activities, while husbands are principally responsible for bread-winning activities. Although these statistical numbers are in keeping with empirical evidence, there are still lingering questions that cannot be readily answered by simply looking at the descriptive statistical numbers:

- *To what extent is this gender difference in travel behaviors attributable to household interactions (as opposed to social influences)?*

- *To what extent is this gender difference in travel behaviors attributable to urban form?*
- *Is there any way to reverse this pattern over time through the changes in household interactions and urban form?*

6 Estimation results

In accordance to the hypotheses in Section 4, the analytical models of this study are designed to investigate whether activity pattern choices are affected by relative power relations in families, urban form, and family attributes. Given the large number of explanatory variables of the study, the models are constructed in an incremental fashion so that the effect of each causal factor can be isolated step by step. As a result, five models in this study are divided into two groups.

The first group of models (Model 1-3) consists of multinomial logit models with daily activity patterns of spouses (husbands and wives) that are intended to detect the effect of the relative powers of family members on the decision of daily activity pattern choice.

Table 6.1The group of models about household interaction

	Model 1	Model 2	Model 3
	Unitary model	Collective model	Collective model
Household attributes	×		×
Disproportionate bargaining power		×	×

The second set of models (Model 3-5) comprises of three models that are intended to test the dual effect of location characteristics and household interactions. The model results separate the effects of different independent variables on males and females by introducing the interaction terms of a dummy gender variable and the independent variables.

Table 6.2 The group of models about household interaction and urban form

	Model 3	Model 4	Model 5
	Collective model	Unitary model	Collective model
Household attributes	×	×	×
Disproportionate bargaining power	×		×
Urban Form		×	×

An explanation of the meaning of the notations of the model variables is provided as follows:

Table 6.3 The explanation of the model variable notations

Variable (alternative)	Explanation
Regular term: Variable (Alter1)	The extent to which the variable will affect the likelihood of wives to choose Alterative 1.
Example: B_CHILD6 (F)	The extent to which the presence of children under six years old will affect the likelihood of wives to choose house-sustaining work.
Interaction term: Wives with the variable indicates fathers' decisions (Alter1)	The extent to which fathers' decisions will affect the likelihood of wives to choose Alternative 1.
Example: Wives with W_A (F)	The extent to which fathers' decisions on taking on the bread-winning responsibility (W+WI+WF+WFI) will affect the likelihood of wives to choose house-sustaining work.

6.1 The model of household interactions

In Table 6.4, Model 1 is a typical unitary model that presents the estimation results using the household attributes only. In Model 1, family members are assumed to be homogenous, beside the gender dummy variable, it does not describe other heterogeneity between spouses. The estimation results obtained from the activity generation model with considering the varying

bargaining powers in a family are illustrated in Model 2 and Model 3. Specifically, the difference between Model 2 and Model 3 is that in Model 2, household attributes are absent. Both Model 2 and Model 3 are benchmarked against Model 1.

More concretely, the first model (Model 1) assumes the travel and activity decisions vary by household attributes such as the number of children, household sizes, and household income levels. On the other hand, the second and third models (Model 2 and Model 3) assume the decisions of married partners are contingent on not only household attributes but also the actual activity and travel decisions made by certain family members. Specifically, the decisions of married partners are governed by the activity programs of children, and female spouses' decisions are also presumed to be susceptible to male heads' daily activity programs. In Model 2 and Model 3, the way of interrelated decision-making among family member on activity patterns is specified by Coefficient 21- 46. The difference between Model 2 and Model 3 is that Model 2 is in absence of household attributes.

Since the eight activity alternatives are assumed to be independent, multinomial logit models are adopted. These models are estimated by maximum likelihood methods in Biogeme, and the base alternatives are the activity pattern of staying at home (NONE).

Table 6.4 The effects of household interactions on the daily activity pattern choices of spouses

		Model 1 (adj. R^2= 0.133)			Model 2 (adj. R^2= 0.150)			Model 3 (adj. R^2 = 0.152)		
	Variable (alternative)	**Value**	**Std err**	**t-test**	**Value**	**Std err**	**t-test**	**Value**	**Std err**	**t-test**
	Alternative specific constants									
1	ASC_1NONE		--fixed--			--fixed-			--fixed--	
2	ASC_2W	0.926	0.0443	20.9	1.15	0.0412	27.96	0.912	0.0512	17.83
3	ASC_3WF	0.0262	0.0412	0.64	-0.26	0.0597	-4.36	-0.326	0.0597	-5.46
4	ASC_4WFI	-1.17	0.0582	-20.04	-1.37	0.0754	-18.2	-1.41	0.0752	-18.76
5	ASC_5F	0.533	0.0499	10.68	0.291	0.0567	5.13	0.221	0.06	3.68
6	ASC_6FI	-0.215	0.0446	-4.83	-0.535	0.0679	-7.88	-0.614	0.0681	-9.02
7	ASC_7I	-0.873	0.0523	-16.71	-0.945	0.0658	-14.35	-0.94	0.0662	-14.2
8	ASC_8WI	-1.02	0.0551	-18.49	-0.828	0.0646	-12.83	-0.817	0.0648	-12.61
	Household attributes									
9	B_CHILD6 (F)	-0.746	0.107	-6.97				-0.181	0.127	-1.42
10	Wives with B_CHILD6 (F)	0.874	0.123	7.11				0.385	0.149	2.59
11	B_CHILD16 (F)	-0.782	0.0815	-9.59				-0.458	0.122	-3.77
12	Wives with B_CHILD16 (F)	1.11	0.0883	12.52				0.585	0.142	4.12
13	B_CHILD6 (W)	0.0501	0.0663	0.76				0.12	0.0689	1.74
14	Wives with B_CHILD6 (W)	-0.807	0.112	-7.21				-0.496	0.119	-4.16
15	B_CHILD16 (W)	0.44	0.0549	8.01				0.561	0.0632	8.88
16	Wives with B_CHILD16 (W)	-0.836	0.0754	-11.09				-0.601	0.0949	-6.33
17	B_HSIZEOVER5 (F, FI)	0.036	0.0541	0.67	-0.0295	0.056	-0.53	-0.0316	0.0562	-0.56
18	B_3G (F, FI)	0.0513	0.0527	0.97	0.134	0.0549	2.44	0.128	0.0554	2.31
19	B_HIGHINC (W)	-0.243	0.0626	-3.88	-0.243	0.0627	-3.88	-0.224	0.0632	-3.55
20	B_LOWINC (F)	0.487	0.0515	9.46	0.549	0.0521	10.54	0.542	0.0525	10.32
	Husbands' travel and activity decisions(W_A, F_A)									
21	Wives with W_A (W)				-0.598	0.0651	-9.2	-0.336	0.0725	-4.64

22	Wives with F_A (W)	-0.318	0.0597	-5.32	-0.193	0.0609	-3.16
23	Wives with W_A (I)	0.289	0.0902	3.21	0.279	0.0908	3.07
24	Wives with F_A (I)	-0.205	0.0972	-2.11	-0.209	0.0976	-2.14
25	Wives with W_A (F)	0.315	0.0634	4.97	0.348	0.0656	5.3
26	Wives with F_A (F)	-0.0233	0.054	-0.43	-0.00361	0.0545	-0.07
27	Wives with W_A (FI)	0.296	0.0769	3.85	0.374	0.0775	4.82
28	Wives with F_A (FI)	0.06	0.0633	0.95	0.0959	0.0636	1.51
29	Wives with W_A (WF)	-0.0287	0.0818	-0.35	0.0414	0.0821	0.5
30	Wives with F_A (WF)	-0.0311	0.0674	-0.46	0.000237	0.0676	0
31	Wives with W_A (WI)	-0.458	0.116	-3.95	-0.48	0.116	-4.12
32	Wives with F_A (WI)	-0.286	0.113	-2.54	-0.302	0.113	-2.66
	Young children's travel and activity decisions(W, I)						
	F specific variables						
33	W (F)	-0.487	0.0533	-9.14	-0.195	0.0765	-2.56
34	Wives with W(F)	0.676	0.0614	11	0.273	0.0897	3.05
35	I (F)	-0.154	0.0524	-2.94	0.00988	0.057	0.17
36	Wives with I (F)	0.449	0.0664	6.76	0.204	0.0723	2.82
	FI specific variables						
37	W (FI)	-0.575	0.0821	-7	-0.424	0.0831	-5.1
38	Wives with W (FI)	0.633	0.0926	6.84	0.452	0.0944	4.79
39	I (FI)	0.242	0.0486	4.98	0.281	0.0492	5.71
40	Wives with I (FI)	0.43	0.0648	6.64	0.347	0.0655	5.29
	WF specific variables						
41	W (WF)	0.343	0.0372	9.24	0.47	0.0397	11.85
42	Wives with W (WF)	-0.199	0.0602	-3.31	-0.357	0.0631	-5.65
43	I (WF)	0.148	0.0364	4.05	0.18	0.0374	4.8
44	Wives with I (WF)	0.138	0.0671	2.05	0.0614	0.0679	0.91
	WFI specific variables						

45	W (WFI)	0.359	0.0546	6.57	0.484	0.0559	8.65
46	Wives with W (WFI)	-0.306	0.0862	-3.55	-0.445	0.0874	-5.09

The explanatory power increases as more variables are included into the model by enough to improve the models' goodness-of-fit. As indicated by Table 6.4, Model 2 and Model 3, which depicts interrelated decision-making among household members, account for much more variation in the choices of daily activity patterns than Model 1. Compared with Model 1, Model 2 and Model 3 result in significant improvements on the goodness-of-fits: the adjusted rho square increases from 0.133 in Model 1 to 0.152 in Model 3. By contrast, the difference of adjusted rho squares between Model 2 and Model 3 indicates that the inclusion of the actual activity programs contributes more greatly to explain the choice of daily activity patterns than the traditional approach of using household attributes.

In addition, the noticeable differences between the model coefficients imply that the estimates from models that fail to consider household interactions, like Model 1, may be biased.

1. Household attributes

The group of household attribute variables (the presence of children of different ages) that traditional household interaction studies (that is, the unitary models) often employed to mirror household interactions still plays a significant role in understanding married partners' decisions on daily activity patterns, as evidenced by Model 1 and Model 3. Confirming the initial hypotheses, Model 1 and Model 3 consistently show that the presence of young children (under seventeen) increases the chances of wives to take on house-sustaining responsibilities and the chances of husbands to perform bread-winning responsibilities. However, the larger household size (over five persons) does not necessarily lead to the choice of family-maintenance activity patterns (that is, F and FI). However, the presence of grandparents does increase the probability of carrying out house-sustaining work during the weekdays. Moreover, the daily activity patterns

of high-income households are characterized by the fewer activity pattern of "W," whereas for low-income households, F activities seem to be more prevalent.

Despite the similar effects exerted by household attributes derived from Model 1 and Model 3, the magnitudes of these effects seem to differ substantially between the two models. Notably, after introducing household interaction terms into the model specification in Model 3, the magnitudes of household attribute coefficients (Coefficient 9 - 20) decrease. For example, Coefficient 10 and 12 in Model 1 seem to have overestimated young children's (under seventeen years old) influence on mothers' work and maintenance decisions by showing that mothers are more likely to assume house-sustaining with the presence of young children. On the other hand, in Model 3, after the household interaction variables are introduced, the effects of household attribute variables on mothers' activity decisions drop from 0.874 and 1.11 to 0.385 and 0.585, respectively. In Model 3, the presence of young children is further supplemented by the variables that indicate whether the children go to school or other extra-curriculum activities; therefore, the presence of young children alone is no longer the single contributing factor to mothers' maintenance decisions. Overall, the distinct degrees of the effects of household attributes shown between Model 1 and Model 3 imply that the actual travel and activity decisions of family members are different from the household attributes and, thus, require a separate treatment in travel demand modeling. Often, the model that includes the actual activity decisions made by the dominant family members is more advantageous and provides more explanatory powers.

2. Household interactions

Perhaps the most interesting effects revealed by Model 2 and Model 3 are those related to household interactions, that is, the effects of aggregated activity-pattern decisions made by

young children and husbands. As revealed by the variables of husbands' decisions (from Coefficient 21 to 32) on work-related daily activity patterns (including W, WF, WI, and WFI), there is still a significant tendency for female spouses to shoulder house-sustaining when male heads to shoulder wage-earning responsibilities. Particularly, wives' choices of the F and FI activity patterns are significantly affected by husbands' decisions to take on work responsibilities. Although husbands' willingness to carry out house-sustaining work decrease the likelihood of wives to undertake house-sustaining (F and FI), this relationship is not statistically significant.

Notably, this substitution between husbands and wives does not operate in the opposite direction: even when husbands take on the house-sustaining responsibilities, it does not ease wives' housekeeping burdens, nor does it encourage wives to enter job market (W and WF). For example, the negative values of Coefficient 21 (-0.318) and 32 (-0.286) indicate that husbands' choices of undertaking house-sustaining work have also lowered wives' utilities of carrying out W and WI and thus do not help wives to participate in the labor market. This seemingly peculiar result may be due to some aspects of household interactions that this model fails to capture. Note that this model only captures the one-way influence among family members, where only husbands' decisions are assumed to affect that of mothers but not the other way around. Perhaps, although wives tend to shoulder more house-sustaining work, the extra portion of house-sustaining tasks would overflow to husbands. However, since in this paper, I do not examine how wives' choices of housekeeping activities will affect other family members' activity patterns for the sake of computational convenience, the actual validity of the above speculation still needs further scrutiny.

It is noteworthy that this asymmetry in substitution may also imply some missing links within the causal mechanism of interrelated decision making between husbands and wives; as a result, the causality may be difficult to establish. For instance, the probability of wives to carry out work-related activity patterns could be also attributed to a consequence of other factors except household interactions. Specifically, the low ratio of women's participation in the labor force in Santiago, Chile may also be attributed to the external socioeconomic context such as workplace discrimination or social conventions that are yet to be modeled.

Another noteworthy finding of Model 2 and Model 3 with the explicit consideration of household interactions is the out-of-home activities of young children tend to encourage the F activity pattern, while discouraging the WF activity pattern by spouses.

Additionally, another significant finding of Model 2 and Model 3 is that when spouses are preoccupied with house-sustaining burdens, they would be less likely to pursue leisure activities (such as eating outside, visiting friends, and entertaining). As illustrated by Model 2, when male spouses are engaged in housework, it may indicate a family has a great demand for house labor; therefore, the probability for females to enjoy personal leisure time is small (see Coefficient 24 and 32).

6.2 The models of household interactions and land use effects

Building on the above understanding of household interaction effects, Model 4-5 are constructed to examine how the inclusion of built environment characteristics would change the correlation between household interaction and activity decisions of married partners. Model 4 and 5 are present in Table 6.5. Also in Table 6.5, the results from Model 3 with only household interactions are replicated for the sake of comparison. Model 4 presents the estimation results that only incorporate the land use characteristics as the independent variables. In the model

specification of Model 5, I not only include the four land use characteristics but also distinguish land use effects on husbands from that on wives. Similar to the models in Table 6.4, since the eight activity alternatives are assumed to be independent, multinomial logit models are adopted for the three models. These models are estimated by maximum likelihood methods in Biogeme, and the base alternatives are staying at home (NONE).

Because Model 5 offers more explanatory powers than Model 3 and Model 4 by including built environment characteristics, the adjusted rho square of Model 5 has increased considerably from 0.147 (Model 4) and 0.152 (Model 3) to 0.157 (Model 5), indicating that there are some variability in the dataset that is not adequately captured by household interactions alone.

Notably, after considering built environment effects, the way that husbands' decisions affect wives' activity patterns has changed, whereas the way that children's activity patterns influence married partners' decisions remains almost the same. Specifically, different from Model 3, Model 5 shows that husbands' undertaking of bread-earning responsibilities does not significantly lead to the falling of house-sustaining (F and FI) on wives (Coefficient 25 and Coefficient 27); on the other hand, husbands' decisions on house-sustaining significantly reduce the probability of wives to shoulder work commitments (would be attributed to the same reasons speculated above). Furthermore, as evidenced by Coefficient 46 and Coefficient 50, whether wives are more likely to undertake house-sustaining tasks seems to depend on the presence of young children, land use characteristics, and self-selection. Yet, household interactions do not prove to be relevant. This counter-intuitive result, the understating of the influence of household interactions, may be due to the fact that the model (Model 5) is misspecified. However, it may also hint at the possibility that household interactions (especially, the bargaining powers of

family members) do not even constitute a reason to account for the task allocation of work and house-sustaining between wives and husbands. To test the existence of household interactions and the influence of unequal bargaining powers, further studies are still needed.

Compared Model 4 with Model 5, the inclusion of household interactions does not change the way that land use affects travel and activity decisions. However, several interesting findings do emerge from the two models that distinguish the effects of land use on wives and husbands. As revealed by both Model 4 and Model 5, land use characteristics seem to have significantly different impacts on married partners. Overall, the results of Model 5 seem to imply a dichotomy of lifestyles between city and suburb households. For example, distances from residences to the CBD seem to negatively affect the likelihood of husbands to choose several activity patterns that have house-sustaining episode (F and FI) (Coefficient 45 = -0.363), while the same land use characteristics tend to encourage wives to carry out F and FI activity patterns (Coefficient 46 = 0.403). In general, the model results suggest that the farther one's home is away from the CBD (and, possibly, the longer daily commuting distances), the less likely for husbands to carry out house-sustaining tasks, and the more likely for wives to choose activity patterns such as F and FI.

However, it appears that work-related activity patterns, especially WF and WFI, do not comply with the above observation. As expected, the proximity to CBD turns out to increase the chances for married couples to choose the WF and WFI activity patterns. This implies a spatial pattern of daily activity pattern choices, where working-parent families are likely to concentrate in the city center. On the opposite, families with housewives tend to inhabit on the suburb.

Despite the activity-pattern differences between families dwelling in the city center and on the suburb, it is still hard to determine whether such results can be attributed to land use

characteristics or self-selection. It is also possible that households with more house-sustaining tasks would prefer the periphery of the city (or the housing prices at the center of the city are prohibitively expensive to them and they have to inhibit where they live now), while households with less house-sustaining are more inclined to staying at the city center. Therefore, the reasons that give rise to this city-suburb difference in lifestyles, or more precisely, travel behaviors, may have nothing to do with household interactions or built environment.

Quite opposite from the initial hypotheses, meso-scale built environment such as neighborhood density, and land use mix around the residence places do not seems to relax the spatial constraints faced by families in Santiago. These urban form elements turn out to be negatively associated with husbands' choices of house-sustaining tasks (Coefficient 49 = -0.766), while they are positively linked to wives' choices of house-sustaining (Coefficient 50 =1.18). Particularly, contradictory to what Ettema (2007) found, diverse land uses near one's home do not prompt husbands to take on more maintenance tasks; instead, they decrease the likelihood of husbands to choose F and FI. This result indicates the possible unobserved causal relationships such as self-selection or macro-level social influences that have yet to be accounted by the model.

Table 6.5 The effects of household interactions and urban from on the daily activity pattern choices of spouses

		Model 3 (adj. R^2=0.152)			Model 4 (adj. R^2=0.147)			Model 5 (adj. R^2=0.159)		
	Variable (alternative)	**Value**	**Std err**	**t-test**	**Value**	**Std err**	**t-test**	**Value**	**Std err**	**t-test**
Alternative specific constants										
1	ASC_1NONE	0	--fixed--		0	--fixed--		0	--fixed--	
2	ASC_2WORK	0.912	0.0512	17.83	0.912	0.0444	20.54	0.91	0.0512	17.77
3	ASC_3WF	-0.326	0.0597	-5.46	0.708	0.127	5.57	0.288	0.135	2.13
4	ASC_4WFI	-1.41	0.0752	-18.76	-0.486	0.133	-3.64	-0.74	0.143	-5.19
5	ASC_5F	0.221	0.06	3.68	0.789	0.112	7.02	0.639	0.12	5.32
6	ASC_6FI	-0.614	0.0681	-9.02	0.0352	0.111	0.32	-0.199	0.125	-1.59
7	ASC_7I	-0.94	0.0662	-14.2	-0.873	0.0523	-16.71	-0.919	0.066	-13.93
8	ASC_8WI	-0.817	0.0648	-12.61	-1.02	0.0551	-18.49	-0.804	0.0649	-12.38
Household attributes										
9	B_CHILD6 (F)	-0.181	0.127	-1.42	-0.264	0.0871	-3.03	0.0984	0.13	0.75
10	Wives with B_CHILD6 (F)	0.385	0.149	2.59	0.249	0.0978	2.54	-0.0568	0.153	-0.37
11	B_CHILD16 (F)	-0.458	0.122	-3.77	-0.369	0.11	-3.36	-0.263	0.123	-2.14
12	Wives with B_CHILD16 (F)	0.585	0.142	4.12	0.293	0.127	2.31	0.309	0.144	2.15
13	B_CHILD6 (W)	0.12	0.0689	1.74	0.0455	0.0665	0.68	0.133	0.0689	1.93
14	Wives with B_CHILD6 (W)	-0.496	0.119	-4.16	-0.775	0.113	-6.83	-0.504	0.12	-4.21
15	B_CHILD16 (W)	0.561	0.0632	8.88	0.413	0.0557	7.4	0.572	0.0631	9.06
16	Wives with B_CHILD16 (W)	-0.601	0.0949	-6.33	-0.771	0.0793	-9.73	-0.594	0.0958	-6.2
17	B_HSIZEOVER5 (F, FI)	-0.0295	0.056	-0.53	0.0324	0.0547	0.59	-0.0333	0.0564	-0.59
18	B_3G (F, FI)	0.134	0.0549	2.44	0.0593	0.0548	1.08	0.114	0.0562	2.03
19	B_HIGHINC (W)	-0.243	0.0627	-3.88	-0.183	0.0635	-2.89	-0.168	0.064	-2.62
20	B_LOWINC (F)	0.549	0.0521	10.54	0.493	0.0525	9.38	0.514	0.0532	9.66
Husbands' travel and activity decisions (W_A, F_A)										
21	Wives with W_A (W)	-0.336	0.0725	-4.64				-0.369	0.0726	-5.08
22	Wives with F_A (W)	-0.193	0.0609	-3.16				-0.201	0.0608	-3.31

23	Wives with W_A (I)	0.279	0.0908	3.07				0.236	0.09	2.62
24	Wives with F_A (I)	-0.209	0.0976	-2.14				-0.229	0.0975	-2.35
25	Wives with W_A (F)	0.348	0.0656	5.3				0.0734	0.0819	0.9
26	Wives with F_A (F)	-0.00361	0.0545	-0.07				-0.0352	0.0645	-0.54
27	Wives with W_A (FI)	0.374	0.0775	4.82				0.0742	0.0697	1.07
28	Wives with F_A (FI)	0.0959	0.0636	1.51				-0.128	0.0555	-2.3
29	Wives with W_A (WF)	0.0414	0.0821	0.5				-0.508	0.116	-4.38
30	Wives with F_A (WF)	0.000237	0.0676	0				-0.309	0.113	-2.74
31	Wives with W_A (WI)	-0.48	0.116	-4.12				0.233	0.0877	2.66
32	Wives with F_A (WI)	-0.302	0.113	-2.66				0.0685	0.0688	1
Young children's travel and activity decisions (W, I)										
33	W (F)	-0.195	0.0765	-2.56				-0.177	0.076	-2.33
34	Wives with W(F)	0.273	0.0897	3.05				0.279	0.0893	3.13
35	I (F)	0.00988	0.057	0.17				0.0329	0.0568	0.58
36	Wives with I (F)	0.204	0.0723	2.82				0.173	0.0721	2.4
37	W (WF)	0.47	0.0397	11.85				0.413	0.0405	10.21
38	Wives with W (WF)	-0.357	0.0631	-5.65				-0.213	0.0665	-3.2
39	I (WF)	0.18	0.0374	4.8				0.164	0.0378	4.36
40	Wives with I (WF)	0.0614	0.0679	0.91				0.117	0.0689	1.7
41	W (FI)	-0.424	0.0831	-5.1				-0.264	0.0825	-3.21
42	Wives with W (FI)	0.452	0.0944	4.79				0.258	0.0947	2.72
43	I (FI)	0.281	0.0492	5.71				0.362	0.0493	7.35
44	Wives with I (FI)	0.347	0.0655	5.29				0.229	0.0659	3.47
Land use characteristics										
45	B_CBD (F, FI)				-0.438	0.0785	-5.58	-0.363	0.0804	-4.52
46	Wives with B_CBD (F, FI)				0.548	0.0809	6.78	0.403	0.0845	4.76
47	B_DENSITY (F, FI)				-0.00252	0.000712	-3.54	-0.00232	0.000716	-3.24
48	Wives with B_DENSITY (F, FI)				0.00244	0.00085	2.87	0.00161	0.000864	1.86
49	B_DI (F, FI)				-1.06	0.336	-3.15	-0.766	0.342	-2.24
50	Wives with B_DI (F, FI)				1.64	0.357	4.59	1.18	0.37	3.2
51	B_RDEN (F, FI)				-0.207	0.523	-0.4	-0.0205	0.523	-0.04
52	Wives with B_RDEN (F, FI)				0.228	0.644	0.35	0.178	0.647	0.28
53	B_CBD (WF, WFI)				-0.299	0.0792	-3.77	-0.323	0.0816	-3.95

54	Wives with B_CBD (WF, WFI)	-0.203	0.0958	-2.12	-0.228	0.103	-2.21
55	B_DENSITY (WF, WFI)	0.000294	0.000615	0.48	0.000308	0.00062	0.5
56	Wives with B_DENSITY (WF, WFI)	-0.000544	0.000978	-0.56	-0.00108	0.000998	-1.08
57	B_DI (WF, WFI)	-0.157	0.326	-0.48	0.208	0.332	0.63
58	Wives with B_DI(WF, WFI)	-0.884	0.421	-2.1	-1.41	0.442	-3.19
59	B_RDEN (WF, WFI)	-2.02	0.496	-4.06	-1.76	0.5	-3.52
60	Wives with B_RDEN (WF, WFI)	-0.872	0.812	-1.07	-0.884	0.819	-1.08

7 The prediction results

The models derived above only predict the probabilities of how individuals make the activity pattern choices. However, predictions for a specific individual are generally of little use in the development of TDM strategies. Instead, either capital improvements or non-capital TDMs are based on the forecast of aggregated demands, that is, the market shares of activity patterns. This Section presents travel demand forecasts in two different scenarios: the business-as-usual scenario and the scenario of increasing bargaining powers of women.

7.1 The short-term prediction: the business-as-usual scenario

In the short term, the bargaining power relation in families in Santiago is assumed to remain unchanged. The estimated coefficients in Table 7.1 and Table 7.2 are therefore applied to forecast the short-term travel demands with and without modeling household interactions. The preliminary predicted outcomes display the considerable biases in travel demand caused by the lack of considering the interdependency decision making between spouses.

Although the interdependency of activity patterns among family members has long been recognized, studies relying on unitary models seldom resolved this problem adequately. In order to quantify the magnitude of discrepancies between predicted results obtained from the unitary model (Model 1) and the collective models proposed (Model 3), the aggregated prediction is performed for the pair of decisions made by both married couples. Unlike the estimation model, the predicted decision outcome here is not a single activity pattern chosen by individual spouses but rather a product of the wife's and husband's activity patterns, denoted by ($act_{husband,i}$, $act_{wives,i}$). There are 64 possible combinations of the activity patterns between wives and husbands that are calculated by timing the eight activity patterns of wives with the eight activity patterns of husbands.

Since disaggregated travel demand is usually not meaningful to inform travel demand management strategies, the predicted individual travel demand (the probability of choosing a certain activity pattern) is aggregated to compute the market share of the families (a married couple counts as one) that choose each possible combination of activity patterns. This market share of the families that choose (act_h, act_w) (where (act_h, act_w) is one of the 64 activity pattern pairs) is calculated using the following equations:

$$P(act_{husband,i}, act_{wives,i}) = \hat{p}(act_{husband,i}) * \hat{p}(act_{wives,i}), i \text{ indicates household } i$$

$$Mareketshare(act\_h, act\_w) = \sum_{N_{(act\_h,act\_w)},i} P(act_{husband,i}, act_{wives,i}) * 100 / N_{(act\_h,act\_w)},$$

where $N_{(act\_h,act\_w)}$ is the total number of families in the estimation set that choose the (act_h, act_w) activity pattern.

Table 7.1, below, lists the predicted market shares calculated using the estimated parameters of Model 1 (the unitary model), Model 3, and Model 5. The predicted travel demands are compared among the three models by using the following equation:

(Ratio(act_h, act_w)$_{\_model3}$ - Ratio(act_h, act_w) $_{\_model1}$) * 100 / Ratio(act_h, act_w) $_{\_model1}$

Table 7.1 The predicted travel demands of spouses by Model 1, 3, and 5

Choice (husbands)	Choice (wives)	Market shares predicted by Model 1	Market shares predicted by Model 3	Total families in the sample	Percentage difference between model 1 and 3
NONE	NONE	1.39	1.44	143	4.0
NONE	W	2.76	4.49	80	62.3
NONE	WF	1.55	1.37	34	-11.8
NONE	WFI	0.43	0.35	8	-18.5
NONE	F	3.72	2.97	178	-20.2
NONE	FI	1.15	1.29	67	12.3
NONE	I	0.58	0.54	42	-7.1
NONE	WI	0.53	0.6	8	13.0
W	NONE	4.53	4.64	322	2.4
W	W	8.11	7.78	398	-4.1

W	WF	4.82	4.06	171	-15.7
W	WFI	1.47	1.09	27	-26.0
W	F	13.24	13.7	907	3.5
W	FI	3.73	5.98	264	60.2
W	I	1.85	2.35	158	27.2
W	WI	1.51	1.25	41	-17.5
WF	NONE	1.53	1.81	84	17.9
WF	W	2.53	2	135	-20.8
WF	WF	1.69	1.98	147	17.3
WF	WFI	0.52	0.52	25	-1.4
WF	F	4.01	6.35	285	58.3
WF	**FI**	**1.27**	**4.25**	**132**	**234.9**
WF	I	0.59	0.68	30	15.6
WF	WI	0.61	0.32	19	-47.2
WFI	NONE	0.47	0.53	13	12.6
WFI	W	0.88	0.64	27	-26.9
WFI	WF	0.5	0.59	37	18.6
WFI	WFI	0.15	0.16	35	7.8
WFI	F	1.17	1.63	52	38.5
WFI	**FI**	**0.38**	**1.02**	**78**	**165.3**
WFI	I	0.21	0.22	9	7.6
WFI	WI	0.18	0.11	20	-39.6
F	NONE	2.23	2.61	102	17.1
F	W	4.11	4.27	129	3.8
F	WF	2.02	1.61	39	-20.4
F	WFI	0.33	0.14	4	-56.6
F	F	4.98	4.37	258	-12.3
F	FI	1.67	1.85	54	11.3
F	I	0.89	0.69	35	-22.8
F	WI	0.76	0.57	9	-24.6
FI	NONE	1.2	0.88	35	-26.3
FI	W	2.16	1.77	31	-18.0
FI	WF	1.17	0.79	10	-32.3
FI	WFI	0.39	0.2	9	-48.7
FI	F	2.94	1.74	64	-40.9
FI	**FI**	**0.96**	**1.84**	**95**	**91.6**
FI	I	0.51	0.33	19	-36.3
FI	WI	0.43	0.33	6	-24.6
I	NONE	0.6	0.56	23	-5.4
I	W	1.14	1.65	19	44.8
I	WF	0.58	0.46	8	-20.5
I	WFI	0.21	0.19	1	-8.8
I	F	1.47	1.07	47	-27.4
I	FI	0.46	0.46	22	-1.4
I	I	0.25	0.19	50	-21.8
I	WI	0.24	0.24	2	1.4
WI	NONE	0.58	0.73	30	26.9
WI	W	0.97	1.14	44	16.7
WI	WF	0.6	0.62	29	2.4
WI	WFI	0.19	0.19	15	-0.4

WI	F	1.35	1.8	96	33.7
WI	**FI**	**0.44**	**0.91**	**81**	**107.2**
WI	I	0.23	0.28	24	21.8
WI	WI	0.2	0.19	20	-6.1

Table 7.2 The most popular activity patterns of spouses as predicted by Model 1, 3, 5

Choice (husbands)	**Choice (wives)**	**Market shares: % (Model 1)**	**Market shares: % (Model 3)**	**Market shares: % (Model 5)**	**Total families in the sample**	**Percentage difference between model 1 and 3**	**Percentage difference between model 3 and 5**
W	F	13.24	13.70	14.84	907	3.5	8.33
W	W	8.11	7.78	7.81	398	-4.1	0.43
W	NONE	4.53	4.64	4.89	322	2.4	5.30

Over all, as listed in the above table (Table 7.2), among all the family activity patterns, (husbands: W, wives: F) is the most common one (907 out of 5150), followed by (husbands: W, wives: W) (398 out of 5150), and (husbands: W, wives: NONE) (322 out of 5150).

Although the predicted market share do not vary considerably for these three family activity patterns, the incorporation of household interactions does make a difference for the rest of combinations of activity patterns (See Figure 7.1). Particularly, as seen from Figure 7.3, it seems that after accommodating household interactions using the game theoretical framework, the prediction of Model 3 shows that the specialization of house labors between spouses will be more prevalent in the future. Specifically, as predicted by the model, the market shares of husbands choosing W and WF as well as wives choosing F and FI increase, at least, by 10%, compared with the travel demand projected by the model without household interaction (Model 1). Among all the combinations of activity patterns, the following contribute the most to the above changes: (husbands: WF, wives: FI), (husbands: WFI, wives: FI), and (husbands: FI, wives: FI) (see the highlighted rows in Table 7.1). The model forecasts indicate that more males and fewer females are expected to carry out work activities. If this increase in male workers

outnumbers the decrease in female workers, the net result may be an increase in daily commuting.

Table 7.3 The predicted travel demands by Model 1, 3, and 5

	Male spouses			Female spouses		
Choice	**Total number of female spouses**	**market share:% (model 1)**	**market share: % (model 3)**	**Total number of male spouses**	**market share:% (model 1)**	**market share:% (model 3)**
NONE	560	12	12	752	12	13
W	**2288**	**38**	**40**	**863**	**22**	**20**
WF	**856**	**12**	**16**	**475**	**13**	**11**
WFI	271	4	5	124	4	3
F	**629**	**17**	**16**	**1887**	**32**	**34**
FI	**269**	**10**	**7**	**793**	**10**	**17**
I	172	5	5	367	5	5
WI	339	4	5	125	5	3

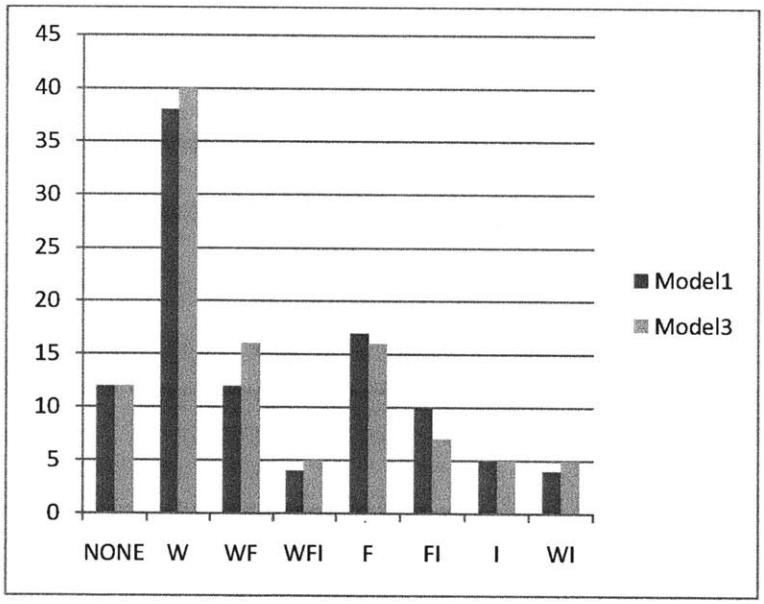


Figure 7.1a The predicted market shares (%) of males choosing each activity pattern

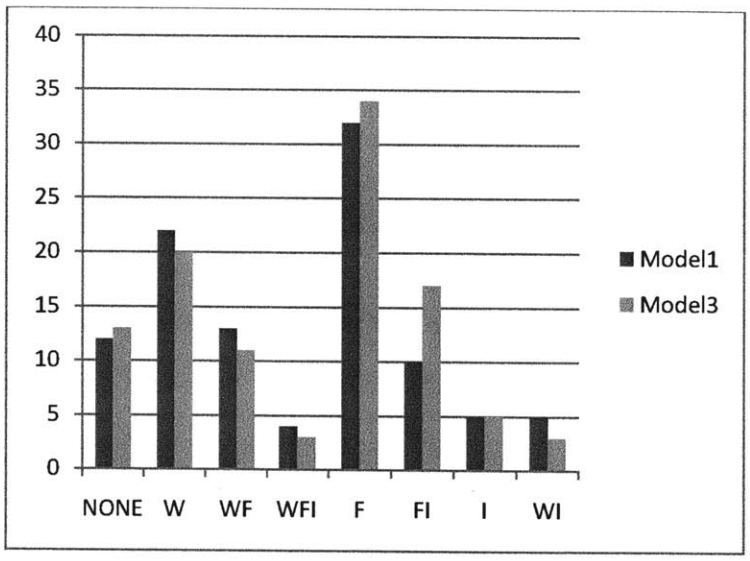


Figure 7.2b The predicted market shares (%) of females choosing each activity pattern

7.2 The long-term prediction: the scenario of increasing bargaining powers of women

Note that the above analysis only showcases the differences in the predictions between Model 1 and Model 3 in the previous section. This focus on the present travel demand does not provide any insights into what the challenges of transportation demand management (TDM) the city may face if the *bargaining power relations between spouses are not fixed over time*. The biggest question for the future Santiago is whether the changes in the household dynamics will affect travel behavior of both men and women.

Given that the future of Santiago may take various paths, scenario planning is a useful approach to render all the plausible alternatives for policy decisions and to test the sensitivity of the city's future in response to different policy initiatives. Here, one possible scenario is contemplated in which the city is assumed to undergo a gender egalitarian movement while all the else remain the same. In this scenario, female spouses have an increasing saying for travel and activity decisions; thus, the influences that husbands have on wives may reduce

substantially. This decline in influences of husbands is operationalized by setting the coefficients of husbands' decisions to zero in the prediction model.

Notably, considering the bargaining power relations between spouses allows for greater variation in the predicted travel demands. More concretely, this scenario, compared to the business-as-usual scenario using the coefficients of Model 1, displays a clear trend of diminishes in household labor specialization. Overall, as seen in Table 7.4, although (husbands: W, wives: F), (husbands: W, wives: W), and (husbands: W, wives: NONE) are still the most common activity pattern combinations chosen by spouses, work-related activity patterns of wives in generally increase noticeably. Specifically, as shown in Table 7.5 and Figure 7.2b, the probabilities of female spouses choosing W and WF have increased by 32% and 8%, respectively. At the same time, the market shares of female spouses to perform F-related activity patterns such as F and FI have plummeted by 16%. Nonetheless, the model predicts that the vast majorities of wives still choose F. Whether this number is overestimated or not, the potential gap between the model prediction and the future reality is likely to be attributed to the entry barriers of labor market or other macro-level factors that are not modeled here. After all, note that the models specified in this paper are not poised to predict the long-term decision of labor participation.

Table 7.4 The predicted travel demands in the long-term scenario

Choice (husbands)	**Choice (wives)**	**Market share : % Model 1** (business as usual)	**Market share: %** (scenario)	**Total families in the sample**	**Percentage difference between Model 1and Model 3**	**Percentage difference between Baseline and Scenario 1**
NONE	WI	0.53	0.7	8	13	32.13
W	WI	1.51	2.16	41	-17.5	42.87
WF	WI	0.61	0.82	19	-47.2	35.24
WFI	WI	0.18	0.25	20	-39.6	38.80
F	WI	0.76	0.91	9	-24.6	19.67
FI	WI	0.43	0.44	6	-24.6	2.73

I	WI	0.24	0.3	2	1.4	26.18
WI	WI	0.2	0.36	20	-6.1	77.52
NONE	WFI	0.43	0.38	8	-18.5	-12.22
W	WFI	1.47	1.22	27	-26	-16.97
WF	WFI	0.52	0.53	25	-1.4	2.50
WFI	WFI	0.15	0.18	35	7.8	17.93
F	WFI	0.33	0.15	4	-56.6	-53.40
FI	WFI	0.39	0.22	9	-48.7	-44.39
I	WFI	0.21	0.17	1	-8.8	-17.40
WI	WFI	0.19	0.21	15	-0.4	8.05
NONE	WF	1.55	1.33	34	-11.8	-14.01
W	WF	4.82	4.44	171	-15.7	-7.81
WF	WF	1.69	2.13	147	17.3	26.17
WFI	WF	0.5	0.65	37	18.6	30.13
F	WF	2.02	1.51	39	-20.4	-25.37
FI	WF	1.17	0.76	10	-32.3	-35.23
I	WF	0.58	0.47	8	-20.5	-19.73
WI	WF	0.6	0.62	29	2.4	3.10
NONE	W	2.76	3.73	80	62.3	35.16
W	**W**	**8.11**	**11.76**	**398**	**-4.1**	**44.95**
WF	W	2.53	4.07	135	-20.8	60.95
WFI	W	0.88	1.28	27	-26.9	45.80
F	W	4.11	4.57	129	3.8	11.10
FI	W	2.16	1.86	31	-18	-14.06
I	W	1.14	1.41	19	44.8	23.60
WI	W	0.97	1.62	44	16.7	66.69
NONE	NONE	1.39	1.7	143	4	21.97
W	**NONE**	**4.53**	**5.31**	**322**	**2.4**	**17.22**
WF	NONE	1.53	1.88	84	17.9	23.16
WFI	NONE	0.47	0.56	13	12.6	19.67
F	NONE	2.23	2.32	102	17.1	3.97
FI	NONE	1.2	0.88	35	-26.3	-26.75
I	NONE	0.6	0.66	23	-5.4	9.90
WI	NONE	0.58	0.86	30	26.9	47.78
NONE	I	0.58	0.62	42	-7.1	7.34
W	I	1.85	1.93	158	27.2	4.17
WF	I	0.59	0.62	30	15.6	4.61
WFI	I	0.21	0.21	9	7.6	-1.87
F	I	0.89	0.83	35	-22.8	-7.08
FI	I	0.51	0.41	19	-36.3	-18.79
I	I	0.25	0.23	50	-21.8	-6.72
WI	I	0.23	0.25	24	21.8	9.87
NONE	FI	1.15	1.2	67	12.3	4.15
W	FI	3.73	4.67	264	60.2	25.30
WF	FI	1.27	3.17	132	234.9	149.57

WFI	FI	0.38	0.67	78	165.3	75.90
F	FI	1.67	1.46	54	11.3	-12.50
FI	FI	0.96	1.63	95	91.6	69.71
I	FI	0.46	0.49	22	-1.4	5.63
WI	FI	0.44	0.65	81	107.2	46.70
NONE	F	3.72	3.13	178	-20.2	-15.77
W	**F**	**13.24**	**11.17**	**907**	**3.5**	**-15.65**
WF	F	4.01	4.54	285	58.3	13.22
WFI	F	1.17	1.14	52	38.5	-2.77
F	F	4.98	3.96	258	-12.3	-20.44
FI	F	2.94	1.66	64	-40.9	-43.50
I	F	1.47	1.16	47	-27.4	-21.19
WI	F	1.35	1.29	96	33.7	-4.33

Table 7.5 The predicted travel demands in the long-term scenario

	Male spouses				Female spouses			
Choice	**Total number of male spouses**	**market share (model1)**	**market share (model3)**	**market share (scenario)**	**Total number of female spouses**	**market share (model 1)**	**market share (model 3)**	**market share (scenario)**
NONE	560	12	12	12	752	12	13	13
W	**2288**	**38**	**40**	**40**	**863**	**22**	**20**	**29**
WF	856	12	16	6	475	13	11	12
WFI	271	4	5	5	124	4	3	3
F	**629**	**17**	**16**	**16**	**1887**	**32**	**34**	**27**
FI	269	10	7	7	793	10	17	13
I	172	5	5	5	367	5	5	5
WI	339	4	5	5	125	5	3	5

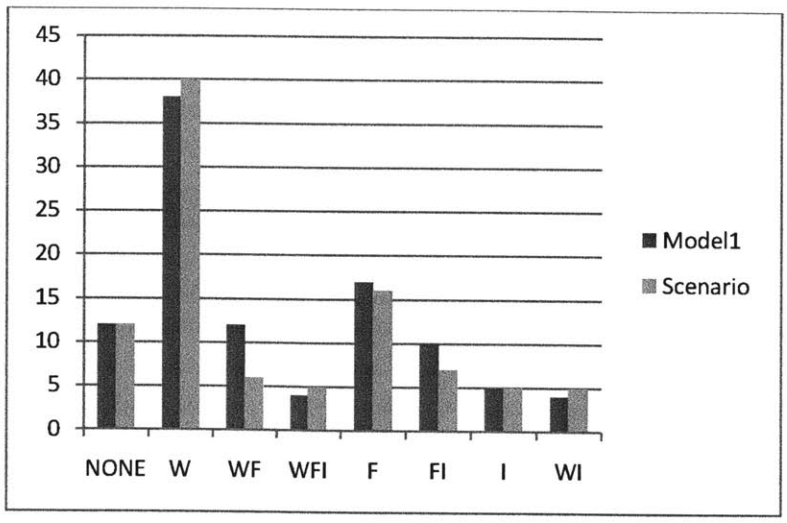


Figure 7.3a The predicted market shares (%) of males choosing each activity pattern

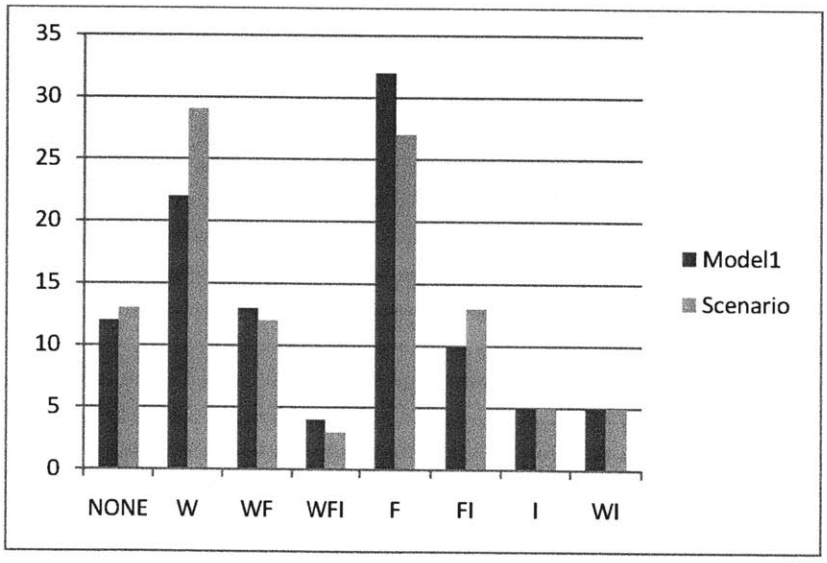


Figure 7.3b The predicted market shares (%) of females choosing each activity pattern

Overall, the model of interdependent decision making is proved to be more sensitive to the changes in household dynamics than the unitary models are. As women gaining more voices over issues such as household task division, a larger number of commuting trips may be induced. At the same time, shopping and escorting trips may have to be chained with commuting trips that are carried out during peak hours to save time. Therefore, these potential changes in activity patterns will not only spur the city's travel demand but also deeply affect automobile usage,

work schedules, and the suburbanization trend of the city (See the next Section for further discussion).

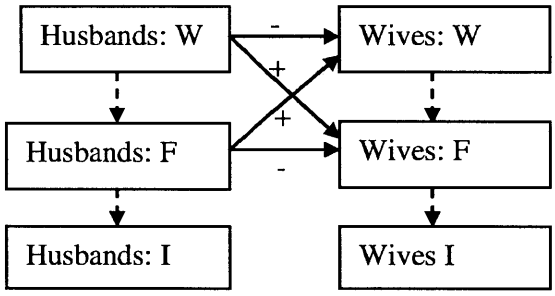
8 Further discussions

8.1 Positive implication: what factors lead to the gender difference in the choice of daily activity patterns?

1. Household interactions

The travel survey of this study has again confirmed the empirical observation that wives remain to perform the majority of the household labor, while husbands continue to take care of families income needs. Specifically, in the estimation set of this study, 50% of the male cohort chooses the W activity pattern, while around 50% of the wives choose the F or FI activity pattern. However, still uncertain are the causes that give rise to this household labor specialization.

In this study, specifically, I hypothesize that the greater bargaining powers of husbands may cause the gender differences in the daily activity pattern choices between spouses. To better summarize the dominance relations between spouses over daily activity pattern decision, Figure 8.1 graphs the hypotheses regarding the influences between spouses.



→: Influences tested by this study

- - - - - - - - →: Influences proved by previous studies

Figure 8.1The hypothesized household interactions

These flows of influences are hypothesized influences between spouses; they do not present an accurate depiction of household interactions in Santiago de Chile. As tested by Model

3 and 5, a few hypotheses about the influences that husbands have on wives turned out to be spurious and counter-intuitive (See Figure 8.2). A relative easy-to-understand conclusion of Model 3 is that husbands' work activities raise the probability of wives to take on house-sustaining tasks and suppress wives' chances to get to work. However, confounded by the built environment's influences and potential intervening effect of self-selection, this interdependency of decision-making between married couples does replicate itself in Model 5. Particularly, the model results show that wives' choice of housework may have nothing to do with husbands' decisions. This finding is nonetheless not conclusive and can be attributed to a variety of reasons such as potential model mis-specification.

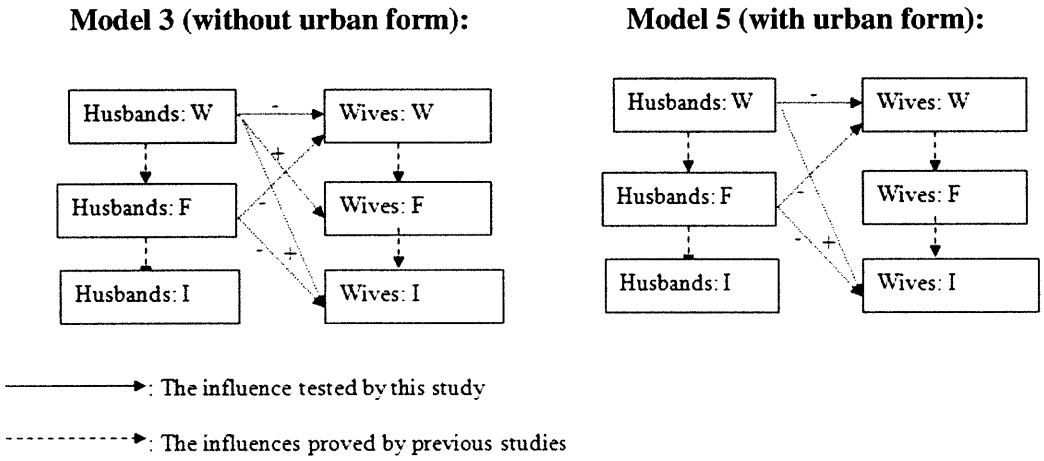


Figure 8.2 the resulted household interactions

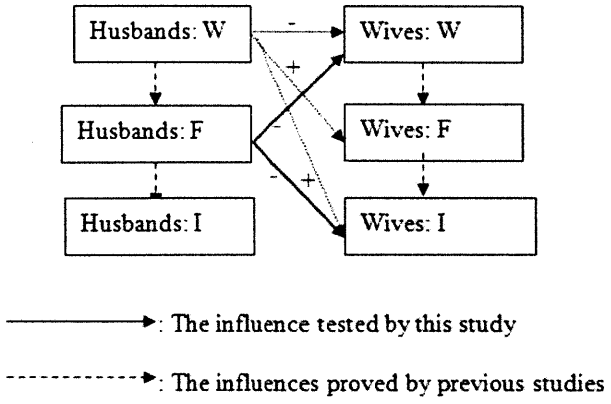


Figure 8.3Model outcomes that run counter to the original hypotheses

However, a relatively puzzling result that cannot be readily explained by this research framework is that the house labor (that is, house-sustaining work) shared by male spouses does not seem to ease but rather increases wives' house-sustaining burdens. Moreover, husbands' house-sustaining decision is not helpful to raise the choice of work-related activity patterns by women (See Figure 8.3). Two possible reasons may account for this peculiarity. First, the simplification of household interactions at the beginning of this study may preclude other bargaining possibilities. For example, women may not be subordinate in all situations. The decision on house-sustaining work by women, particularly the portion of the tasks that are beyond wives' capacity, may determine how much it overflows to husbands.

Second, this result is not too surprising if ones realize that household dynamics are not the only factor that causes the way that families split housework. Based on the 1994 International Social Survey in 22 industrialized countries, Fuwa (2004) found that macro-level factors (such as gender inequality, economic development, female labor-force participation, gender ideology (e.g., females are expected to do housework), and welfare regimes) are equally important in the dynamics of housework division between spouses. Particularly, these macro-level factors may limit the effects of household dynamics on daily activity pattern choices. For example, the

traditional, social attitude to women participating in labor forces may play an important role in the division of housework and probably function as a self-fulfilling prophecy. What may add to the complication is that macro-level factors are also conducive to the formation of micro-level household dynamics. For example, wages are one of major factors that determine the degree of bargaining powers women have in families. However, this aspect is out of the scope of this study.

Overall, without effectively eliminating confounding explanations and accounting for all the mutual influences between spouses' decisions over these activity and travel decisions, the causal relationship between families' dynamics and the task allocation between spouses cannot be conclusively established at this point. Despite the limitation of the model, this study does renew the knowledge of household dynamics and lay the foundation for further analysis. Particularly, it charts out the possible areas where household dynamics may be weak but the influences of macro-level factors may be strong. Building on the improved understanding, a better model of modeling household activity patterns can thus be constructed toward an accurate account of the disaggregated travel behaviors and a better predictability in response to changing environments.

2. Urban Form

Location and urban form would be relevant to the explanations of gender difference in travel patterns because different environments may provide different opportunities or imply different constraints for the task allocation within households. For example, Ettema et al. (2007) found that urban environments offer more opportunities for efficient trip chains, thereby allowing women to combine their maintenance tasks with work and leisure activities. This may

also relax the spatial and temporal constraints faced by families and enable males' participation in maintenance activities. Given the empirical evidence, I hypothesize that males are more likely to engage in maintenance activities, if households reside in an urban center and have a neighborhood with mixed land use, dense grid street network and high residential density (See Figure 8.4a).

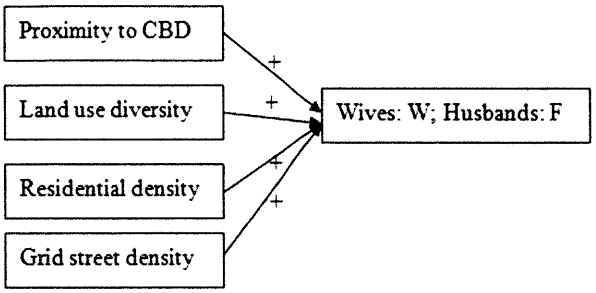


Figure 8.4a Hypotheses of the effects of urban form on household travel and activity decisions

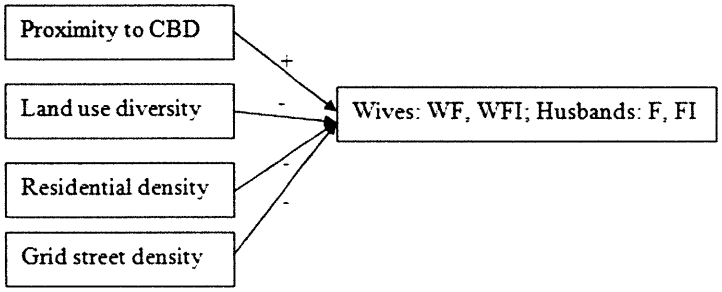


Figure 8.4b The model outcomes about the effects of urban form

The model results verify the existence of spatial variation in gender difference in travel behavior. They also partially confirm the hypotheses that denser and more diverse opportunities available at the city center may encourage husbands to participate in house-sustaining work and wives to go into the job market (Figure 8.4b). However, meso-scale built environment such as neighborhood density and land use mix around the residence places do not seems to relax spatial constraints. Rather, these urban form elements turn out to be negatively associated with husbands' choices of house-sustaining tasks, while they are positively linked to wives' choices of

house-sustaining. Particularly, contradictory to what Ettema (2007) found, diverse land uses near one's home do not prompt husbands to take on more maintenance tasks.

This result may imply the existence of possible unobserved causal relationships such as self-selection that have yet to be accommodated by the model. Likewise, the lack of consideration of car access would also explain the model results that are not anticipated. Particularly, if households on the suburb are characterized by large private vehicle ownership, both partners would be less affected by the layout of their neighborhoods. Thus, the impact of urban form may be trivial. Overall, the rigidity of household travel and activity decisions to the built environment of neighborhoods may question the attempt to use urban design instruments to influence daily activity patterns of spouses. Nonetheless, even if land use instruments could not break the pattern of households' allocating daily tasks, they may as well ameliorate any possible unequal consequences resulting from household labor specialization (see the discussion in the subsection below).

8.2 Normative implications: what are the implications of gender difference in the choices of daily activity patterns?

1. The efficiency implication: travel demand of the society as a whole

Broadly speaking, transportation demand management (TDM) strategies are actions aimed at influencing people's travel behavior so that desired mobility\accessibility goals of a society could be achieved (Meyer, 1997). The success of TDM strategies lies in the improved knowledge of both travel behaviors and behavioral changes. One of the variables that trigger the changes in travel behaviors is family life cycles, where different stages of family life cycles are featured by different travel behaviors. Also noteworthy is even at the same stage of the life cycle, travel behaviors also vary with the changing roles and bargaining powers of family members.

Therefore, if the models are more sensitive to the changes in household dynamics, they could provide more accurate accounts of travel behaviors of women and men. Specifically, with women having greater votes over family travel and activity issues, these models would be able to not only predict the travel demand but also detect the nuances of the market shares of spouses to carry out W, WF, WI, and WFI.

Overall, the models suggest that it does matter if household interactions are measured with reference to households (using unitary models) or to individuals (using the collective models). As demonstrated by my analysis, ignoring the gender difference in task division between spouses and its underlying mechanisms may cause the underestimation of travel demands.

Particularly, with the rising bargaining power of women, the model outcomes on activity pattern choices may imply a considerable increase of travel demand, especially commuting trips by females and house-sustaining trips by male spouses. If this increase in travel demand exceeds the capacities of existing transport infrastructure and services, severe traffic congestions as well as negative externalities that associate with congestions (such as air pollution and energy exhaustion) can result. Although several well-known TDM strategies such as congestion pricing, carpooling, and the improvement of public transit system could be deployed to lessen the increased travel demand (especially the travel demand for private car usage), the implementation of these strategies still have obstacles that are chiefly due to the lack of the specific details regarding when, where, and how certain activities and travel are usually accomplished.

Ideally, the detailed travel and activity decisions and the variability of these decisions can help formulating a well-conceived TDM strategy and ensure the effectiveness of the strategy. For example, McGuckin and Murakami (1995) reported some anecdotal evidence that in the U.S.,

with more and more women gaining bargaining powers in families, the time that the female spouse spent on house-sustaining activities has been squeezed, on average. They also noted that not only women have more time to work; they are also more likely to chain the shopping and escorting trips to and from work. To minimize the cost of trip chaining, policies are prescribed to promote a better mix of land uses and to deliver childcare services near employment sites.

In summary, although daily activity plans are needed to accurately capture the temporal and spatial interdependency between trips and tours in reality, fine-grained travel behaviors such as trip chaining or mode split are also necessary to achieve the personalization of TDM policies and the empowerment of female spouses in families. The prototype models with interdependent decision making in this paper still have to be extended into a real-sense activity-based model with nested layers to represent these hierarchical travel and activity decisions.

Although the models in this study show the limitation to provide refined predictions about the future travel demand in Santiago as a result of an increase in women's participation in labor force, the current travel behaviors of 2-worker families may be informative to extrapolate the future trend of travel demands of the city (See Table 8.1). Overall, revealed from the travel survey of this study, in 2-worker families, the number of maintenance and leisure trips made by wives is much fewer than that in 1-worker families, indicating more time constraints and work-family trades-off faced by 2-worker families. Further, although 2-worker families tend to undertake fewer out-of-home trips, they seem to be better at strategically organizing different trips into one single home-based tour. Moreover, spouses in dual-earner families are also found to commute less time to work, but there is not such a sign showing that women spend even less time than men in commuting, as opposed to what has been found by previous empirical studies. All the evidence together indicates that a behavioral shift from 1-worker families to 2-worker

families, and further implies the necessities for the measures to reduce the trip-chaining costs and commuting time like mixed land use development. Also notably, most commuting trips undertaken by women are through the modes of public transit or walking. Although it is not clear about the future motorization trend of the city, at least at present, the transit system (either the formal ones or the informal ones) may need to be improved to accommodate more woman commuters.

Table 8.1The travel behaviors of 2-worker families vs. 1-worker families

Family type	Ratio of non-commute trips	travel time (commute)	travel time (non-commute)	auto split (commute)	auto split (non-commute)	out-of-home trip rate	Avg. # of trips in a trip chain
1-worker family							
Wives	43.78%	n/a	16.74	n/a	17.59%	1.88	2.24
Husbands	19.88%	42.27	20.83	32%	45.55%	1.36	2.45
2-worker family							
Wives	26.58%	38.96	20.76	28%	41.33%	1.39	2.55
Husbands	22.94%	37.15	20.41	42%	60.95%	1.34	2.72

2. The equity implication: the reduction of intra-household gender inequality

From the equity point of view, the gender difference in the division of housework is an indication of intra-household gender inequality. Often, women's family responsibility disrupts their careers, creating a negative impact on their market wages (Taniguchi 1999) and impeding them to re-assume their careers after a long duration of inactivity in the labor market. Further, Alderman et al. (1995) also noted that "how resources are distributed within households affects the measurement of inequality and poverty." Following this logic, the unequal bargaining power per se is a manifestation of the inferior status of women in families. Unfortunately, many female spouses do not perceive their share of disproportionate house labor as inequality (Lee & Waite

2010). Based on a survey conducted in the U.S. in 1988, Lenon and Rosenfield (1994) reported that only 4.3% of female interviewees believe that housework is unfair to them. Furthermore, they found that women with fewer economic resources (or bargaining powers) are less likely to view their share of housework unfair. Therefore, empowering women and increasing their bargaining powers at home can serve as a viable approach to deal with the inequality problem common in families in Santiago, Chile. Additionally, some scholars have also noted that gender inequality is further aggravated by social exclusion. For example, evidence has shown that although labor participation for women is low in the city of Santiago; however, the ratio is even lower for the poor.

How to attain gender equality, particularly the mobility and accessibility equality for women is still a much-disputed issue. Policy efforts to deal with gender inequality often take place under two different rationales: the passive approach that caters to the special travel demand of women by increasing land use and transportation supplies and the active approach that aims at coordinating the travel demand of females and males by empowering women in families.

2a. Land use planning and accessibility improvement

Model 5 has implied the lifestyle disparities between families living in the city center and that living on the suburb: dual earner families that choose WF and WFI are likely to concentrate in the city center, whereas families with housewives tend to inhabit on the suburb. Whether this pattern is a result of personal preferences or is affected built environment still needs further investigation. Moreover, it is still controversial if land use planning policies should cater to the

demand for different lifestyles at each location, or it is more favorable to counteract such a spatial distribution of travel behaviors (or lifestyles).

By contrast, the relationship between daily activity patterns and meso-scale built environment such as the land use mix of TAZs is more instructive to land use planning. Although plenty of previous studies on the connection between the land use on a meso scale and travel behavior have demonstrated that individuals with different travel purposes tend to be affected by built environment differently, few studies have really link individuals with the social roles they play.

Particularly, as noted above, women still retain the major responsibility for household keeping tasks, while men are primarily in charge of bread-earning responsibilities. After associating individuals with their social roles, or at least the roles that they play in families, it turns out that land use characteristics appear to have divergent impacts on family individuals. For example, housewives are more sensitive to land use mix nearby their residences than husbands when planning family-maintenance activities (F and FI). It also clearly shows in Table 9.1 that wives in 1-worker families are more likely to shop in proximity to their homes via the means of walking or taking public transit. Since carrying out house-sustaining tasks are mandatory, land use segregations and limited accessibility around residence places will be more likely to make wives (or mothers) worse off. This problem in conjunction with social segregation may even worsen women's quality of life. Statistics showed that there is a high proportion (61%) of women who stay in the poor suburban neighborhood as housewives in the city (Fadda 2000). In addition to unequal treatment in the labor market, wives and mothers may have to deal with the uneasiness to carry out house-sustaining work in the city of Santiago. More women than men may be subject to the lack of schools, markets, parks, childcare and healthcare facilities there.

Hence, the lack of considering household interactions could overlook intra-household inequality and the policy initiatives that are not well conceived and would contribute to widening intra-household inequality. Policies that actively reduce this gender inequality could include community services that introduce farmers' markets, flea markets, and childcare systems, and city-level efforts to promote mixed land use or better transit access (by providing either formal or informal transit lines).

2b. Elimination of gender inequality in the division of household labor

To achieve both improving household production efficiency and alleviating the intra-household inequality, many countries have crafted different approaches under various rationales. For non-conservative countries like Chile that strive to promote egalitarian gender ideology, the identification of the causes that lead to unequal division of housework between spouses can facilitate the design of policy solutions. After all, different reasons for the gender difference in the division of tasks may request distinctive policy prescriptions (Fuwa & Makiko 2007). For example, to overcome the macro-level work opportunity obstacles for female spouses, policies can be issued to facilitate females' employment access and remove job entry barriers. These policies could encourage women's access to jobs and economic security, thus promoting women's economic independence (Chang 2000, Orloff 1993). On the other hand, to resolve micro-level unequal bargaining powers between spouses, countries could provide social welfares and protection on an individual rather than family basis in order to financially empower women. Likewise, benefit policies can be crafted to provide housework and childcare services to dual-earner families, particularly the poor, as have been long practiced in countries such as Sweden and Norway (Chang, 2000). However, it is necessary to point out that the policies that are

relevant to the division of household tasks are largely contingent on the ideology of the countries. Still, in conservative countries such as Germany (Esping-Andersen 1999), the exclusion of married women to the labor market and the dependence of wives on their husbands for social security are often accepted with little objection.

To evaluate the effectiveness of the policies that address the issue of intra-household inequality, simply looking at the decision outcomes of activity patterns is not sufficient. The contextual information regarding when, where, and how work and house-sustaining activities are accomplished is also necessary to diagnose if gender difference in the division of tasks still exists or not. For example, even as working mothers, females may also experience unequal treatments in employment schedule (such as night shifts) and employment duration (such as part-time work) compared to the male counterparts. Therefore, it should be stressed that to fully evaluate the gender inequality issue in the division of housework between spouses, ones should look beyond the activity patterns defined above to embrace a more thorough investigation.

2c. Summary

In summary, the approach chiefly relies on land use and transportation interventions to upgrade transit services or rearrange land uses so that the special accessibility demands of women to reach employment or amenities (such as childcare and healthcare services) sites can be satisfied (Riverson 2006). This approach only partially addresses the problem; in the end, gender inequality in families still lingers, where women still heavily take on house-sustaining work. With the relatively subordinate status of women in families, their well-being is much likely to be subject to compromises. On the other hand, the active approach directly targets at the causes underlying the gender difference in travel behaviors. In the end, such an approach regards that

the household division of labor is the main reason[5] that results in the travel behavior differences (Turner & Niemeier 1997, Law 1999). Particularly, regardless of employment statuses, women tend to have greater shares of house-sustaining and child-caring responsibilities. Because of this extra household-sustaining burden, women tend to have to face greater time constraints, which further explain the tendency of women to commute shorter distance and fewer times to workplaces (Turner & Niemeier 1997, Blumen 1994). Aiming at the determinants that give rise to the unequal division of labor within families (for example, breaking the traditional notion that women are the principal caregivers), gender inequality can be better reduced at this source. As a result, this approach may be more socially desirable as it not only improves women's well-being but also increase the inventory of human capital in the society.

8.3 The generalizability of the model and model results

One complication with dealing with the bargaining power of spouses in this paper is that the bargaining power relation often exhibits great variability even among families in the same city. The assumption about the bargaining power that favors male household heads, although may capture the general picture, is much likely to overlook this heterogeneity. An accurate account of the travel behaviors of families in Santiago can be attained by allowing for modeling the heterogeneity of family power relations.

Moreover, as mentioned earlier, household interactions and urban form do not operate on its own; they are often nested in the macro environment that comprises of community and social conventions, and are also affected by individual preferences and capabilities. To the extent of macro-level factors may set the boundary limitation on household interactions, the applicability

[5] Other alternative explanations also exist. For example, studies have found that the unique, intrinsic traits of women such as being weak in navigating (or way-finding) (Lawton 1994) or strong in environmentally consciousness may make women less likely to drive (Matthies 2002).

of the results from this study to elsewhere could be practically limited. For example, with the maturity of tertiary industries, families in many developed countries have the option to outsource their house-sustaining activities (such as cooking or babysitting) to others outside their families. Due to the flourishing of day care agencies, spouses in these countries may undertake fewer house-sustaining activities. Therefore, without examining these macro-level factors, it is sometimes hard to make the generalization about if household interactions or macro level factors are at work.

Likewise, the effects of urban form are also confounded by many unobserved factors. Here, although households' travel behaviors exhibit the urban-suburban bifurcation, the rigidity of household travel and activity decisions to the built environment of neighborhoods may imply the existence of self-selection or the influence of car access. That said, the living habits and preferences of families may influence the choice of neighborhoods; car ownership may lift up some constraints posed by neighborhoods' land use characteristics. Nonetheless, given the varying conditions in different places, the impact of urban form may not be as trivial as observed in this study. Therefore, the applicability of the results from this study to elsewhere has to be treated with great care.

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