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Built Environment and Outdoor Leisure Activity under the Individual Time Budgets

Yongjin Ahn [1] and Jongho Won [2,*]

1 School of Architecture, Seoul National University of Science and Technology, Seoul 01811, Korea
2 Population Studies and Training Center, Brown University, 306 Maxcy Hall, 108 George Street Providence, Providence, RI 02912, USA
* Correspondence: jongho_won@brown.edu

Abstract: Previous studies highlight the role of walkable neighborhoods in improving the health status of residents, hypothesizing that there is a strong relationship between the built environment and individual physical activity. However, unlike theoretical prediction, the evidence is less established that residents in inner cities engage in more physical activity than residents in suburban areas. To address this gap between theoretical prediction and empirical evidence in physical activity studies, this paper investigates the links between the built environment and outdoor leisure activities under the individual time constraint. We conducted path analysis, employing the samples of Los Angeles County in NHTS (National Household Travel Survey, 2008–2009). Empirical results revealed that individual time constraints have a significant negative effect on leisure time spent in outdoors, but the influence was marginal. Surprisingly, the access to local resource (e.g., park area) still matters even after time constraints are controlled for. Regarding the effects of other covariates, safety (perceived), attitude, and disability showed the largest association with outdoor leisure activities amongst the independent variables with the expected sign. Based on these results, this study not only confirms that the lack of time plays a role as a barrier of the outdoor leisure activity, but also proves that park area can be considered as a facilitator. However, the behavioral decision for outdoor leisure activities is about more than time constraints and the built environment since the effects of both are much smaller than other key covariates.

Keywords: built environment; outdoor leisure activity; time-constrains; park area; path-analysis

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1. Background

There has been much concern about low levels of physical activity generally caused by a sedentary lifestyle [1]. Relying on a motorized vehicle and a labor-saving device, people rarely engage in a regular physical activity for transportation and other utilitarian purposes [2]. In addition, people spend more leisure time on sedentary activities than on outdoor activities [3].

Since the lack of physical activity has been highlighted as a major factor of causing numerous physical and mental diseases, including obesity, anxiety, and depression [4–8], it is crucial to identify the mechanism through which physical activity is shaped or governed. Studies have tried to answer the question of 'what factors affect physical activity?' and 'how and to what extent potential factors matter?' Among potential candidates, both individual characteristics and neighborhood attributes are influential factors for physical activity [9–11]. This indicates that the interplay of human behavior and the built environment is essential in this mechanism [12,13].

However, the connection between the built environment and physical activity is still unclear since there are many covariates and confounding factors that obscure the connection. To be specific, the effect of built environment could vary across different persons and different spatial contexts [11,14]. For example, in general, inner-city neighborhoods offer pedestrian-friendly urban form and physical features that are normally missing in suburban neighborhoods [15]. Therefore, it is generally expected that residents in inner cities are more likely to engage in physical activities than residents in suburban areas [16,17]. The empirical evidence which supports the theoretical prediction, however, is less established [18–21].

To address the discrepancy between theoretical prediction and empirical evidence in physical activity studies, this paper investigates the links between the built environment, time constraints, and physical activity. Specifically, this study views time budget as a third variable to explain the potential reason of "urban-suburban paradox", assuming that a time constraint might reduce the opportunity to engage in outdoor physical activity [15] p. 171.

We revisit the relationship between the built environment and physical activity for both (active) travel and recreation by incorporating individual's time constraints based on the specific information of trips, time allocation, and location. Focusing on Los Angeles County in the southern California region, we test whether time-constraint factors influence physical activity and, if so, how and to what extent; whether the connection between built environment and physical activity is still valid while controlling for time constraint factors; and whether there is a significant chain of relationships between the built environment, time constraints, and physical activity.

The major contribution of this study on the relationship between the built environment and physical activity is incorporating the concept of time constraints based on individual's daily time allocation. By quantifying the interrelationship between the built environment, time constraints, and physical activity, this study will improve the major findings from previous works. For example, incorporating the time constraints in physical activity may provide grounds for explaining why residents in an inner-city neighborhood are normally in a low level of physical activity even though they live in the built environment which facilitates being active.

2. Literature Review: What Determines Physical Activity?

Empirical studies, which have explored the relationship between various characteristics of built environment and various types of physical activity, have produced mixed results. One strand of studies found the positive influence of residential density and access to services on physical activity [22,23], whereas other studies also revealed the negative influence of intersection density and access to commercial facilities on physical activity [14,24].

Although the mixed results could be due to different case areas, samples, measurements, and analytic methods of each study, different theoretical frameworks could also be influential. For example, from the psychological perspective, the theory of planned behavior highlights the role of intrapersonal values, arguing that belief is the unique factor which makes people induce (or prompt) behaviors as a set of outcomes [25]. According to this perspective, behavioral, normative, and control belief are the three types of belief that affect individuals' attitudes, subjective norms, and perceived behavioral control (ibid). Furthermore, in explaining behavior, Ajzen proposed a framework that stresses the mediating role of intention between attitude, subjective norm, perceived control, and behavior, rather than emphasizing the role of the built environment.

Meanwhile, the literature in the field of planning and public health has focused on the role of the built environment in engaging physical activity. The effect of neighborhood attributes might be proven by spatial variation in the level of physical activity as well as in the prevalence of obesity [26–30]. The findings of these studies explain the reason why individuals living in a different place have different health-related behaviors and health outcomes.

This argument is also supported by socio-ecology theory which suggests both the holistic view of human environment and some dialectic unification between behavioral and environmental approaches [12,13,31]. In this theoretical frame, individual behaviors are influenced by multiple facets of the environment (e.g., physical, social, political, and cultural) as well as by multilevel settings of system (micro-, meso-, exo-, and macro system) [32,33]. Within this perspective, most physical activity studies argue that the built environment with physical configurations for 'active living' encourages physical activity and hence can lead to a healthy status.

In sum, earlier studies have normally placed their focuses on the direct link between the built environment and physical activity. However, the findings from previous studies, which not only demonstrate the relationship between the built environment and physical activity but also assess policy strategies devoted to the environmental change for behavioral change, are mixed [18,19]. The interplay of human behavior and environment is still elusive. Some studies also conclude that empirically the role of the built environment is not significant or marginally significant, and that the built environment alone rarely explains the level of physical activity [21,34–36].

This suggests the consideration of time constraints in the relationship between built environment and physical activity. As a complementary platform for the utility-maximizing theory of travel, the activity-based approach assumes that travel demand is derived from the needs or desires to participate in various activities and amenities which are spatially and temporally varying [37,38]. In the activity-based frame, the trade-off between the benefit from obtaining activities and the cost for travel is a major determinant of the choice of activity [39]. Based on this behavioral mechanism, individuals allocate their time budget for a specific activity and travel [40]. Physical activity in the various outdoor places follows the nature of time budget as well. However, unlike other essential and mandatory activities in a daily life, physical activity is generally a discretionary activity and travel. Under the discretionary choice, people can be more affected by time budget as a major constraint.

More importantly, physical activity is related with diverse factors, including intrapersonal values, individual's time-budget, and financial resources along with both individual compositions and contextual values. Intrapersonal values either confound or mediate the role of built environment on physical activity. In addition, both 'time' and 'income' factors can also play crucial roles as constraints which reduce physical activity. For example, the lack of time is often cited as a barrier which reduces the opportunity to engage in physical activity [41–43]. In this sense, the effect of the built environment cannot be properly captured without considering two constraints. Of constraints, economic constraints can be mostly controlled by individual income and median income at the neighborhood. However, the specific effect of individual time constraints, in conjunction with the role of the built environment, still remains unknown in previous studies [36,44].

The difficulties in determining the role of the built environment in physical activity is another challenge. Like other behavioral studies, the uncertainty ascribing to the lack of information is the most critical data issue. That is, the researcher rarely knows specific locations of both person and physical activity. Either the absence of the specific location geo-coded or the presence of loose geographic information also makes it difficult to define a geographic unit, raising a modifiable areal unit problem. Thus, we can hardly disaggregate the characteristics of the built environment with more fine-grained measurements.

Furthermore, given that physical activity can occur in various behavioral settings such as housing, school, and workplace, the location-based approach to physical activity is required to investigate the individual effect of different exposures [45]. However, unlike other travel survey datasets, health survey datasets often used in physical activity studies provide little information on the spatial-distribution and time-allocation of physical activity.

3. Research Framework

To overcome the limitations mentioned before, this study suggests a more comprehensive research framework for physical activity. As illustrated in Figure 1, the conceptual framework includes several paths which represent the complex relationship between individual characteristics, time constraints, built environment, and physical activity measured by total time spent in various types of outdoor places, based on individual's daily trips.

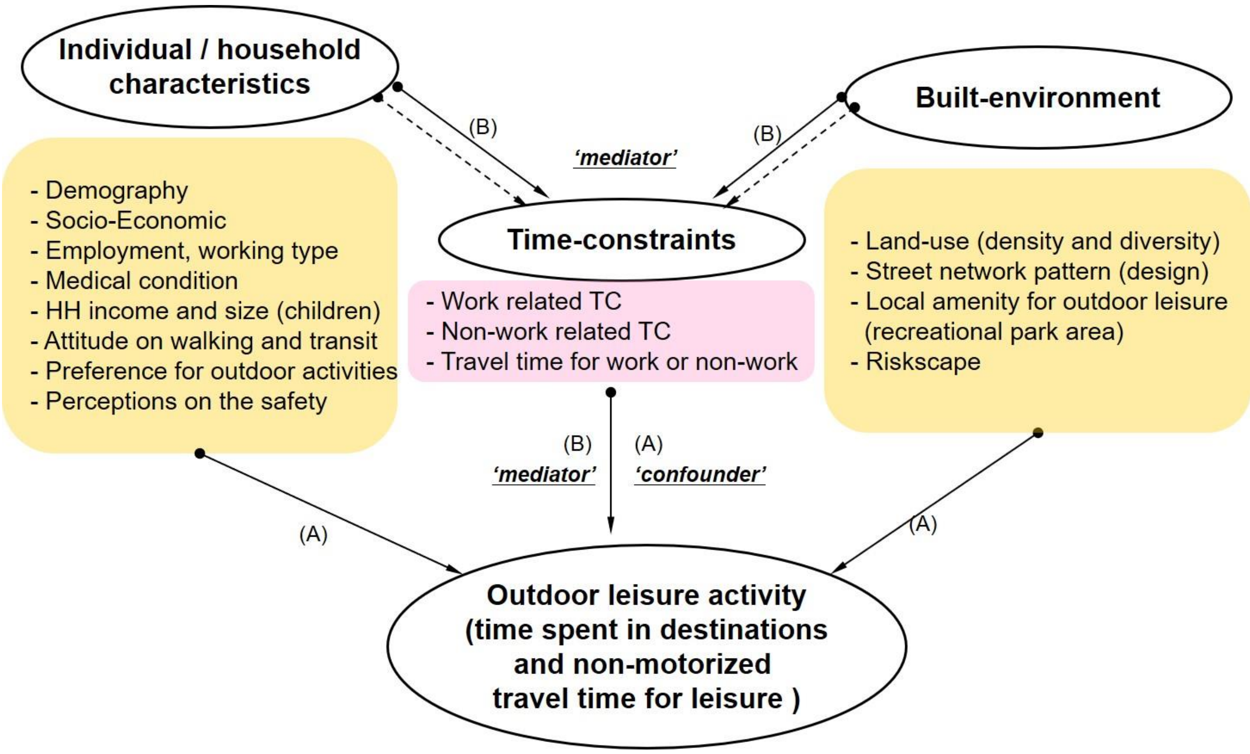

Figure 1. Potential links between individual, intrapersonal, time constraints, the built environment, and PA time spent. (Note) (A) indicates the direct effect by a confounding variable; (B) indicates the indirect effect by a mediating variable.

More specifically, individual/household characteristics on the left side in the diagram contain demo-socio-economic status and intrapersonal factors such as attitude, preference, and perception. The factors of the built environment on the right side include several physical configurations (e.g., land use and street network pattern) and local amenity for outdoor leisure activity (e.g., a recreational park area). As a third variable, time constraints can be broadly defined by the activity (including travel per se) with a non-discretionary fashion under the individual time budget. In this paper, the time constraints are categorized as three types: work-related time constraint, non-work-related time constraint, and the time spent in non-discretionary travel.

Both individual/household characteristics and the attributes of the built environment can affect directly or indirectly outdoor physical activities. Path (A) explains the direct effect, whereas path (B) indicates the indirect effect mediated by the time constraints. In this process, not only individual/household characteristics but also built environment can affect the time constraints.

By and large, a time-constraint factor can play a role as a mediating and a confounding variable. To better understand the difference between those roles of time constraints, two assumptions are required. The first presumption is that there might be a strong link between an individual (or the built-environment) and the time constraint, as illustrated by a dashed-line. Under this strong-link assumption, the time constraints can also play as a mediator, as Path (B) refers to. The other presumption is that there might be a weak link between an individual (or the built environment) and the time constraint. Unlike the strong link, the time constraint can play as a confounding variable under a weak-link assumption. That is, the time constraint can be seen as a third variable which directly influences physical activity, as Path (A) represents.

4. Data and Method

The primary data source of this study is National Household Travel Survey (NHTS, 2008–2009) from the California add-ons which consists of total 3381 households (6161 persons and 21,062 trips) living in Los Angeles County, California. This data contains the measurement of individual time constraints based on the information of trips, time allocation, and location, while controlling other crucial covariates. The strength of the NHTS data is the information of the geo-coded location (i.e., x-y coordinates) of the household, workplace, and each trip (i.e., origin and destination), as well as 241 variables related to the person, household, and trip information. The latest version of California add-ons was updated in 2017. However, unfortunately, it no longer offers the geo-coded information of the household, workplace, and each trip due to the confidential issue. Given the limited availability of data, we employed California add-ons dataset conducted in 2008 and 2009.

We incorporated several personal variables such as medical conditions for travel, demo-socio-economic characteristics, the attitude toward walking and public transportation, and the perception of the built environment. Household variables employed in this model fall into household income and household size. Trip inventories consist of trip summaries on trip purpose, mode, travel time and distance (length), and time-spent at destinations.

In addition, we utilized the 2008 GIS data of the Southern California Association of Governments (SCAG) and the street network data which contain land use information at the parcel level and street pattern, respectively. Those allow for the objective measure of 3D (Density, Diversity, and Design) factors as well as the access to local resources (e.g., a recreational park area) as a destination for outdoor physical activity. As many previous studies hypothesized, 3D factors can be understood as a proxy for the accessibility for destinations. For example, density measure is usually employed to explain the variation in travel outcome and physical activity even though it masks other confounding factors. Some studies revealed the significant relationship between density and several travel behaviors, including low level of personal travel and high level of walking/public transportation use [46–48]. Diversity, which refers to "the co-location of multiple uses", may also affect access to the services and destinations thereby reducing travel distance as well as time [36,49].

Furthermore, as one of the design elements, the objective measurement of the street intersection (or 'cul-de-sac') provides the vehicle with information for the conceptualization of urban form and design features which affect physical activity. For example, a high (or low) connectivity may improve (or reduce) access to possible destinations within a specific distance in all directions, and finally it decreases (or increases) travel distance as well as time. Although 3D factors are somewhat ambiguous and implicit, access to the park area captures directly the explicit characteristic of urban form, answering the question of whether people who live nearby parks conduct more physical activity there. By merging the NHTS dataset and the SCAG GIS/street network data, we constructed a data structure of physical activity (PA) devoted to the outdoor.

Table 1 indicates the definition and measurement of variables. First of all, the dependent variable in this model is the time spent at outdoor destinations for physical activity which includes walking/bike travel time for leisure. Usually, a walking and/or bike trip for leisure activities do not have specific amounts of time at a destination, but travel time can be also considered as a physical activity at the outdoor place. More importantly, the NHTS dataset does not clearly classify the type of physical activity in terms of outdoor/indoor. Therefore, we separated physical activity into outdoor and indoor places, using the tool of 'spatial joint' in ArcGIS 10, and randomly checked the places on the satellite map. We also calculated individuals' walking/bike travel time for leisure activities using the trip information of the NHTS dataset and then added the value into the physical activity time spent at destinations.

Table 1. Definition and source of variables.

Variables	Code	Definition	Source (Year)
PA time spent	PATIME	Outdoor PA time (dwelling), including walking/bike travel time for leisure	NHTS (2008,9)
Type A	TCONA	Work-related time constraint	NHTS (2008,9)
Type B	TCONB	Non-work-related time constraint	NHTS (2008,9)
Type C	TCONC	Travel time for TCONA and TCONB	NHTS (2008,9)
Total TCs	TOCON	Type A + Type B + Type C	NHTS (2008,9)
Age	AGE	5 to 99	NHTS (2008,9)
Gender	GENDR	Male = 1; Female = 0 (Ref.)	NHTS (2008,9)
	RACE_W	White (Ref.)	NHTS (2008,9)
	RACE_H	Hispanic	NHTS (2008,9)
	RACE_B	Black	NHTS (2008,9)
	RACE_A	Asian	NHTS (2008,9)
	RACE_O	Others	NHTS (2008,9)
Education	EDC	Less than High School = 1; High School & College = 2; Bachelor over = 3	NHTS (2008,9)
HH income/person	HHICP	HH income/family size	NHTS (2008,9)
Labor(job) type	JOBTY	Blue = 1; Others = 0 (Ref.)	NHTS (2008,9)
Disability	DISAB	Disable = 1; Able = 0 (Ref.)	NHTS (2008,9)
Attitude	ATTIT	How often use public transit last month?	NHTS (2008,9)
Safety	SAFETY	Not concerned = 1; Concerned = 0 (Ref.)	NHTS (2008,9)
Weekday/end	WKDE	Weekend = 1; Weekdays = 0 (Ref.)	NHTS (2008,9)
Weather condition	WTHC	Not Winter = 1; Winter = 0 (Ref.)	NHTS (2008,9)
Density	DENS	HU density (units/square mile), Census tract level	SCAG (2008)
Diversity	DIVS	Entropy index for land use type (R/C/O/P)	SCAG (2008)
Design	INTRSCT	Street connectivity (3 ways+)	SCAG (2008)
	CULDES	Cul-de-sac	SCAG (2008)
Destination	N_PARK	Number of parks	SCAG (2008)
	A_PARK	Total area of parks	SCAG (2008)
Commute Distance	T_CD	Job-housing distance	NHTS (2008,9)

In large, independent (or explanatory) variables fall into four types: (1) time constraint, (2) individual characteristics including demo-socio-economic status and intrapersonal values, (3) exogenous variables such as weekend/days and weather/season, and (4) built environment. First of all, three types of time constraints were measured: work-related time, non-work-related time, and travel time for both, by sorting out the purpose of the trip in the NHTS dataset which categorizes trip purpose into 37 items. More specifically, work-related time constraints (Type A in Table 1) can be defined as the time spent at destinations in purpose of 'work and school', 'attending business meeting/trip', and 'school/religious activities'. On the other hand, non-work-related time constraints were measured by calculating the time spent at destinations in purpose of 'OS-day care', 'medical/dental services', 'shopping/errands', and 'buying goods/services' (Type B). The third type of time constraint was measured by calculating travel time spent in both work-related and non-work-related time constraints (Type C).

Next, variables for individual/household's demo-socio-economic status and intrapersonal values are also available in the NHTS dataset. More specifically, this empirical model incorporates several individual compositions: age ranging from 5 to 99, gender (dummy: 'female' is a reference group), race (categorical: 'White' is a reference group), education, HH income divided by family size, and labor type (categorical: 'white color' type is a reference group). Intrapersonal values contain disability ('not disabled' is a reference group), attitude for walking and public transit, and safety (dummy: 'concerned about safety' is a reference group).

Last, the neighborhood was defined as a 1/4 mile buffer area from the location of the household with the more fine-grained resolution. Based on this catchment area, most of the physical configurations in the built environment were measured except for density. More specifically, housing density (i.e., housing units per square mile) was measured at the census tract level. The entropy index captures the diversity among different land-use types: residential, commercial, office, and recreational [50]. Using the SCAG network GIS data, we measured design factor which represents two contrasted street patterns: '3 or more intersections' (i.e., high street connectivity) and 'cul-de sac' (i.e., low street connectivity). Access to the park area, which is a proxy for local amenity for outdoor leisure activities, was measured by counting the number of parks, as well as by calculating the total area of park within a buffer area. Commute distance was obtained from the NHTS dataset as a proxy for job-housing distance. In addition, as pointed out by several studies, two crucial exogenous variables regarding the season (dummy: 'winter' is the reference) and date (dummy: 'weekdays' is a reference) were controlled in order to explain properly the variation in physical activity [51–53].

As a methodology issue, a causal relationship between the built environment and physical activity is another challenge. Not only lack of information based on a longitudinal dataset but also hypotheses derived from a less explicit theoretical frame make it difficult to establish a causal link [54]. To address the complex hypothetical model among individual compositions, contextual values, time constraints, and outdoor physical activities, this study will conduct path analysis. As a unique analytic method, a path model allows for sorting out the chain of relationship, identifying effectively the mediate, moderate, and latent effect of explanatory variables and separating both the direct and indirect effects [55,56]. In addition, path analysis provides some clues to causal influence, dealing with endogenous variables, and allowing for global assessments of model fit [57].

This paper suggests the path model which explains potential links within a conceptual framework (Figure 1). More specifically, path analysis deals with the relationship between individual/household characteristics (X), the built environment (W), a time constraint (T), exogenous variables (Z), and PA time spent (Y). As mentioned earlier, time constraints can play different roles not only as a confounder (i.e., Equation (1)) but also as a mediator (i.e., Equations (2) and (3)), depending on whether there is a weak or strong link between individual/household (or the built environment) and a time constraint.

$$Y = b_{01} + b_{X1}X + b_{W1}W + b_{T1}T + b_{Z1}Z + e_{Y1} \tag{1}$$

$$T = a_{02} + a_{X2}X + a_{W2}W + e_{T2} \tag{2}$$

$$Y = b_{03} + b_{X3}X + b_{W3}W + b_{T3}T + e_{Y3} \tag{3}$$

The direct effect of individual/household, built environment, and exogenous variables on PA time spent can be denoted by 'b_{X1}', 'b_{W1}', and 'b_{Z1}', respectively. More specifically, in Equation (1), a set of 'b_{X1}' includes HH income, the perceived safety, attitude, and disability; a set of 'b_{W1}' contains the characteristics of parks; a set 'b_{Z1}' includes date and season. In addition, the confounding effect of time constraints can be denoted by b_{T1}. In Equation (2), a set of 'a_{X2}' includes several demographic profiles such as age, gender, and race; 'a_{W2}'incorporates urban form features. The indirect effect of time constraints can be denoted by b_{T3} in Equation (3). In this case, 'b_{T3}' should be significant, and both 'b_{X3}' and 'b_{W3}' should be either non-significant or significantly smaller than 'b_{X1}' and 'b_{W1}', respectively.

5. Results

Table A1 in Appendix A shows the descriptive summary which indicates the number of samples, mean, standard deviation, and range from min to max. Prior to path analysis, we checked the multi-collinearity issue among the potential explanatory variables. Since most variables have a VIF value below five except for employment, we removed the variable of 'employment' in the final model for path analysis. Importantly, we considered physical activity as a censored variable since it is latent but an unobserved variable with a non-negative value [58]. To address this issue, we utilized the option of defining the 'censored variable' in M-plus.

The final model with 5086 persons shows a high and statistically significant likelihood ratio chi-square (x2 = 23.47, df = 23, p = 0.0000). Through the additional test for goodness-of fit indices, we confirmed that our empirical model suggests a reasonably good fit (CFI = 0.774, TLI = 0.539, and RMSEA = 0.062 (<0.08)). The explanatory power (R square) of a 'time constraint' and 'physical activity (i.e., outdoor leisure activity time)' model is 0.306 and 0.339, respectively.

Figure 2 visualizes the results from path analysis, focusing on the direct effect. By and large, the final dependent variable (i.e., time at destination) has a direct effect on recreational park, time constraints, and other exogenous/individual variables such as household income, safety, attitude, season, and date. On the other hand, a time constraint, the other dependent variable here, has a direct effect on urban form features (e.g., 3D and commute distance) and individual characteristics.

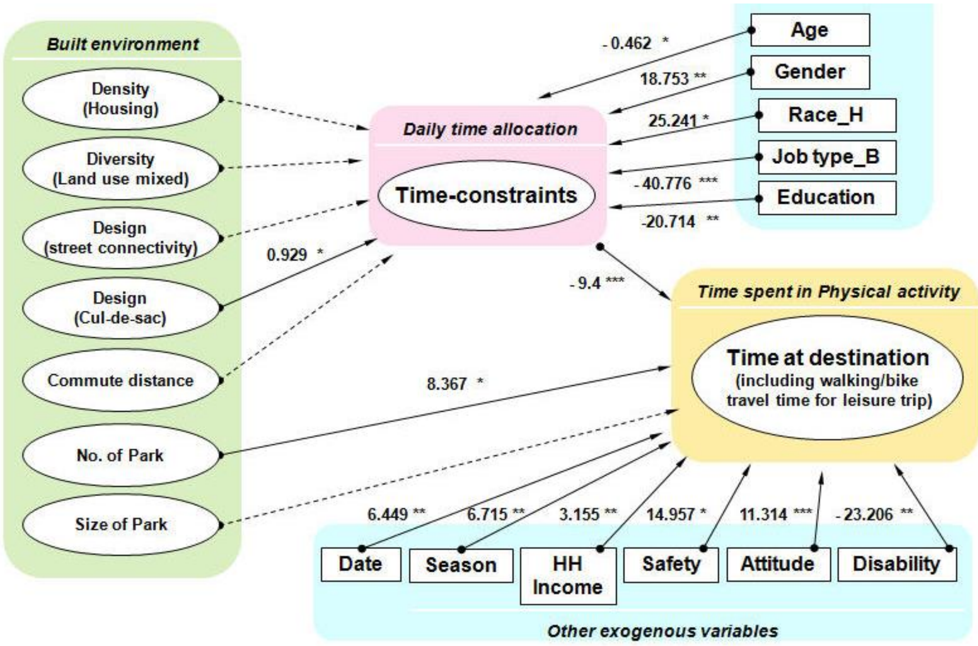

Figure 2. Results from path analysis (direct effects only). (Note) (1) both the direction and significant level of associations appear on single-headed straight arrows (* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). (2) Straight arrows represent significant association; dashed arrows represent not significant association.

Disability, safety concern, attitude, time constraint, date (weekend/weekdays), season, and household income by family size were significantly related to physical activity with an expected sign. More specifically, as expected, disability has the largest effect (beta: −23.206, $p < 0.01$) on physical activity. People with a disabling condition spend less of their time at destinations for outdoor leisure activities by 23 min than people with non-disability.

Two intrapersonal values are also statistically significant. That is, people who do not feel any concern about the safety (beta: 14.957, $p < 0.05$) engage more in outdoor physical activity than people who do. People with much attitude for public transportation (beta: 11.314, $p < 0.001$) spend more time at a destination for outdoor physical activity than people with less attitude.

Regarding exogenous variables, there is a significant effect of date (beta: 6.449, $p < 0.01$) and season (beta: 6.715, $p < 0.01$). As expected, people usually conduct more the outdoor physical activity on weekend days rather than weekdays, whereas people normally conduct less during winter. In addition, this study found that there is a significant association between the number of parks and physical activity (beta: 8.367, $p < 0.05$), but the size of park is not significant.

Next, there was the evident difference in the direct effect on time constraints between individual characteristics and the built environment in terms of significance and magnitude. First, the variables of demo-socio-economic status indicate a significant and relatively large effect. For example, gender (beta: 18.753, $p < 0.01$), Hispanic (beta: 25.241, $p < 0.05$), blue color job (beta: −40.776, $p < 0.001$), and education (beta: −20.714, $p < 0.01$) have a large effect on time constraints, except for age (beta: −0.462, $p < 0.05$), which has a negative but marginal effect. Statistic results show somewhat dynamic relationships with time constraints. That is, male (comparing with female), Hispanic (comparing with White), people in a white color job (comparing with a blue color job type), and people with low education attainment are more constrained in time.

However, there was no significant relationship between 3D factor/commute distance and time constraints in this study. Only cul-de-sac (i.e., low street connectivity) amongst urban form features is significantly associated with time constraints with a positive sign (beta: 0.929, $p < 0.05$), but the size of influence is much smaller than that of other individual characteristics. That is, people who live in a neighborhood with a low connectivity street pattern are likely to be more constrained in time, comparing with people in a well-connected neighborhood.

More importantly, there was a significantly negative association between time constraints and the time spent in physical activity at outdoor places. Based on this finding, we confirmed that lack of time (i.e., the existence of time constraints) plays a role as a barrier which reduces physical activity at outdoor places. However, the influence of the negative effect of time constraints is relatively smaller than that of other exogenous variables. For example, people with 100 min of time constraints conduct less physical activity by 9.4 min.

Table A2 in the Appendix A presents the results from path analysis including the indirect effect of several explanatory variables. Like a direct effect in Figure 2, age (beta: 0.004, $p < 0.05$), gender (beta: −1.761, $p < 0.01$), Hispanic (beta: −2.371, $p < 0.05$), blue color job (beta: −3.83, $p < 0.001$), education (beta: 1.946, $p < 0.01$), and cul-de-sac (beta: −0.087, $p < 0.05$) have also a significant indirect effect on physical activity. However, the direction of indirect effect is opposed, and the size of each influence dramatically reduced. Notably, it is interesting that there is the chain of association between the built environments (e.g., cul-de-sac), time constraints, and physical activity. The magnitude of this chain effect is marginal but statistically significant. This study confirmed that cul-de-sac shows a direct effect (+) on the time-constraint sign, as well as an indirect effect (−) on physical activity. It suggests that a less connected street pattern might increase travel time on a street, and hence this constraint can reduce the opportunity to engage in physical activity.

6. Conclusions and Discussion

Given the importance of physical activity on individuals' physical and mental health, it is imperative to understand the link between the built environment and physical activity while controlling for other crucial factors. The effect of explanatory variables in this model is fairly consistent with literature, except for age and gender. White and high education, safety, non-disability, and season (i.e., not winter), and date (i.e., weekend days) have a significant and positive effect on physical activity as expected. However, both age and gender effect are different from the literature. The time-constraint assumption between the built environment and physical activity is partially supportive since it can reduce directly the time of physical activity at an outdoor place but the size of negative effect is marginal when comparing other key variables. Another point made by our findings is that, amongst the urban form features, the access to park still matters while controlling for time constraints. This implies that local resource (park area) nearby home can directly increase the time spent in physical activity there, and that offering 'many' parks is a more efficient way than creating a 'huge' park area.

Furthermore, we found that the chain of association between the built environments (e.g., cul-de-sac), time constraints, and physical activity also implies that there is a street pattern with low connectivity (e.g., cul-de-sac) which can directly increase the amount of time constraints but also indirectly decrease physical activity. Thus, it is concluded that although a time constraint (i.e., lack of time) was proven as a barrier of physical activity, local resources for physical activity (e.g., recreational park area) play a role as a facilitator. However, the individual's behavioral decision for leisure activities in outdoor places is about more than time constraints and the built environment since both are far less important than safety, attitude, and disability.

Although this study contributes to the literature by incorporating the time constraints to identify the determinants of physical activity, several limitations should be mentioned. First of all, our dependent variable (i.e., PA time spent at outdoor destinations) does not necessarily mean the level of physical activity. That is, more physical activity time does not refer to the vigorous physical activity. To investigate the role of time constraints based on individual daily time-allocation and trip information, we simply assumed that the more people spend their time in the outdoor place for recreation, the more people engage in physical activity. However, the time spent in the outdoor place for recreation might not represent exactly the actual time for physical activity.

Next, we measured several built environment attributes based on a '1/4 mile buffer' catchment area. Even though it allows for more fine-grained measurement, it is still somewhat arbitrary to define the neighborhood as a uniform type of geographic area. In addition, a home-based catchment area captures partially the characteristics of the built environment since there are many behavioral settings where individuals conduct their physical activity. Thus, it is needed to capture additionally other potential places for physical activity. Residential self-selection might also bring a critical methodological issue to the behavioral studies. As mentioned by previous studies, it does not allow for detecting the true effect of the built environment on physical activity. This study did not address self-selection issues since NHTS data does not provide any longitudinal information which allows for before–after comparisons.

Lastly, it is still questionable why residents who live in the walking-friendly built environment typically conduct less physical activity than suburban residents. To shed more light on this discrepancy, it is also required to identify the potential factors which make the different levels of physical activity of different residents. Other barriers which reduce the level of physical activity of inner-city residents will be developed in the future study.

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Appendix A

Table A1. Descriptive summary.

Variable	N	Mean	S.D.	Min	Max
PATIME	6161	27.252	72.9959	0	1230
AGE	6161	45.738	21.84382	5	99
GENDR	6161	0.479	0.499599	0	1
RACE_W	6161	0.6226	0.484769	0	1
RACE_B	6161	0.0651	0.246699	0	1
RACE_A	6161	0.0988	0.298482	0	1
RACE_H	6161	0.1471	0.354189	0	1
RACE_O	6161	0.0253	0.15711	0	1
EDC	5090	2.3244	0.634298	1	3
HHICP *	6161	2.2775	1.7951	0	10
JOBTY_B	6161	0.2052	0.403852	0	1
JOBTY_O	6161	0.7948	0.476101	0	1
DISAB	6161	0.0803	0.271847	0	1
ATTIT	6161	0.2853	0.68665	0	3
SAFETY	6161	0.1063	0.308264	0	1
WKDE	6161	0.2685	0.443196	0	1
WTHC	6161	0.5225	0.499535	0	1
TCONA	6161	146.46	228.3765	0	1020
TCONB	6161	40.826	76.50895	0	845
TCONC	6161	60.458	54.79341	0	750
TOCON	6161	247.75	247.2751	0	1130
N_PARK	6161	0.3624	0.593207	0	4
A_PARK *	6161	2.1636	5.4902	0	68.991
DENS *	6161	0.3467	0.328073	0	3.6714
DIVS	6157	0.3257	0.186593	0.013	0.950227
CULDES	6161	7.1766	8.092604	0	94
INTRSCT	6161	29.713	14.85819	0	161
T_CD	6161	5.485	48.36671	0	2214.99

(Note) '*': Numeric unit was adjusted by multiplying 0.0001.

Table A2. Results from path analysis (Direct and indirect effects).

Variables	Time Constraint (TOCON)			PATIME		
	Beta	***p***	**S.E.**	***Beta***	***p***	**S.E.**
Intercept	455.123	***	20.34	56.807	***	5.061
AGE	−0.462	*	0.195	*0.043*	*	*0.019*
GENDR	18.753	**	6.186	*−1.761*	**	*0.6*
RACE_B	16.648		12.591	*−1.564*		*1.19*
RACE_A	8.041		10.577	*−0.755*		*0.996*
RACE_H	25.241	*	10.18	*−2.371*	*	*0.977*
RACE_O	3.783		19.272	*−0.355*		*1.81*
EDC	−20.714	**	5.453	*1.946*	**	*0.538*
JOBTY_B	−40.776	***	8.648	*3.83*	***	*0.875*
DENS	4.694		9.958	*−0.441*		*0.936*
DIVS	28.841		16.544	*−2.709*		*1.57*
CULDES	0.929	*	0.422	*−0.087*	*	*0.04*
INTRSCT	−0.387		0.233	*0.036*		*0.022*
T_CD	−0.04		0.057	*0.004*		*0.005*
TOCON				−9.4	***	0.008
N_PARK				8.367	*	3.323
A_PARK				0.598		0.346

Table A2. *Cont.*

Variables	Time Constraint (TOCON)			PATIME		
	Beta	*p*	S.E.	*Beta*	*p*	S.E.
SAFETY				14.957	*	5.784
DISAB				−23.206	**	6.611
HHICP				3.155	**	1.027
ATTIT				11.314	***	2.688
WKDE				6.449	**	4.454
WTHC				6.715	**	3.805
R-SQ		0.306			0.339	

(Note) (1) The final dependent variable (i.e., physical activity) was considered as a censored variable. (2) '*Italic*' represents indirect effect (* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$) (3) '*Beta*' represents standardized path coefficients (*Beta* of 'Time constraint' was multiplied by 100, so this means 9.4 min of physical activity per 100 min of time constraints).

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