An Environment-People Interactions Framework for Analysing Children's Extra-Curricular Activities and Active Transport

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ABSTRACT
In this paper, the focus is on examining children's extra-curricular activities in a high density urban East Asian environment, specifically Hong Kong. The paper offers a framework to understand children's extra-curricular activities time allocation and active travel participation. Three variables of interest are considered: residential location choice (based on residential density), weekly time spent in four different types of out-of-home after-school activities (academic, sports, arts, and other), and level of active travel. The proposed model takes into account common observed and unobserved effects that can be affecting the three outcomes simultaneously. Overall, the findings, based on survey data collected at four primary schools between November 2015 and June 2016 in Hong Kong, show that children's activity and travel behaviour within the same city can differ quite substantially based on neighbourhood environment (notably residential density) and family socio-demographic background. The empirical findings and analysis provide insights for policy development, including those related to (a) targeting children's extra-curricular activity participation for underprivileged groups, (b) promoting work-friendly policies that enable parents to spend more time and participate in more activities together with their children, as well as (c) promoting mixed use and compact development to encourage a more active lifestyle for children and parents alike.

Keywords: Children's activity-travel behaviour, MACML estimation, Hong Kong activity-travel, residential location, extra-curricular activity, active travel modes

1. INTRODUCTION

Academic interest in children's mobility with respect to their accessibility to opportunities across different locational and situational contexts has grown quickly over the last decade. This trend has been reflected in the number of manuscripts published in leading transport journals like the *Journal of Transport Geography*. In the last ten years (2009-2018), this journal has published 23 articles directly related to children travels from across the world, including empirical studies in Albania (Pojani and Boussauw, 2014), Austria (Stark et al., 2018a, Stark et al., 2018b), Belgium (Zwerts et al., 2010), Canada (Fusco et al., 2012; Waygood et al., 2017), China (Li and Zhao, 2015; Zhang et al., 2017), Finland (Kytta et al., 2015), Germany (Stark et al., 2018a), Japan (Susilo and Waygood, 2012; Waygood et al., 2017), New Zealand (Lang et al., 2011), Norway (Fyhri and Hjorthol, 2009), Portugal (Lopes et al., 2014), Sweden (Andersson et al., 2012; Waygood et al., 2017; Westman et al., 2013) and the US (McDonald, 2012; Deka, 2013, 2017), as well as other more issue-specific studies (Christie et al., 2011; Ghekiere et al., 2018; Sharmin and Kamruzzaman, 2017; Tranter and Sharpe, 2012). Nonetheless, with 1,199 papers published in the journal during the same period, it is clear that various geographical issues of children travels are still barely unravelled.

In this paper, we emphasize the need for a holistic approach to study children's activity-travel patterns by recognizing that a child's activity-travel patterns are heavily influenced and constrained not only by individual factors (such as gender and age), but also by the characteristics of their parents/family and neighbourhood attributes (Loo and Lam, 2015; Lam and Loo, 2014). The role of parent(s) or guardian(s) as decision-makers (on behalf of the children) is obvious, but other parental influences through lifestyles cannot be ignored. For example, McDonald (2008) found that a mother's lifestyle choice of commuting to work using a private vehicle had a negative impact on her children's propensity to walk or bicycle to school. Deka (2013) also found evidence that the lifestyle choice of household adults' travel mode to work has a strong influence on the travel mode used by children in the household. Neighbourhood attributes also come into play, where evidence has shown that certain mixed-use and pedestrian-friendly neighbourhoods, such as those in well-planned satellite cities and new towns, are conducive to more active and independent travel in children (Loo and Lam, 2015; Lam and Loo, 2014). Indeed, there have been thorough reviews in the literature regarding direct and indirect environmental determinants for children's active travel behaviour, indicating the importance of a variety of neighbourhood-level factors such as travel distance, social cohesion measures, urban form and en-route road safety, amongst other factors, all of which are important to consider for their influence on the activity-travel patterns of children (see for example, Kemperman and Timmermans, 2014; Panter et al. 2008).

Furthermore, children's school-going patterns can also have an impact on the activity-travel patterns and commute mode choices of household adults, as exemplified in the structure of many activity-based models that use the school start and end time of children as time constraints for the parents' schedules, imposing not only an adjustment of work start and end times, but also drop-off/pick-up obligations that influence all the household members' commute mode choices (see Bhat et al., 2004 and Bhat et al., 2013). However, the inter-linkage between adults' and children's activity-travel patterns is not simply confined to the work-related travel of adults and the school-related travel of children. The majority of current evidence suggests that children to a large extent still depend on household adults to drive or take them to extra-curricular activity events outside the realm of children's school activities, especially those from households owning more vehicles in lower density neighbourhoods (Copperman and Bhat, 2007; Paleti et al., 2013;

Hjorthol and Fyhri, 2009). Such serve-passenger activities constrain adults' activity-travel patterns in important ways. In addition to serve-passenger activities, the activity-travel patterns of children and adults get inter-linked in the context of joint activity participations in extra-curricular activities. In other words, the importance of considering the geographical context of these inter-linkages between adults' and children's activity-travel patterns must be recognized. In many cities, public schools are allocated based on students' home locations (Loo and Lam, 2015). Attendance at a neighbourhood school, whether public or private, will have the obvious benefit of reducing the need for young children to travel too far and will also make it easier for a parent (or guardian) to supervise a child between school and home, and by extension, extra-curricular activities. Some parents may even consider moving to so-called better neighbourhoods for a higher chance of their children to be admitted to better schools and better surrounding activity facilities and amenities (Lam and Loo, 2014; Loo and Lam, 2015). From the above, it should be apparent that both children's and adults' activity-travel patterns ought to be considered together within the geographical context of the built environment.

The strong inter-linkage just discussed between children's and adult's activity-travel patterns is not adequately recognized in the literature, which has focused more on the intra-household interactions solely among the adults in the household (see, for example, Zhang and Fujiwara, 2009; Lim, 2015; Kim et al., 2015). The implicit assumption in such an <u>adult-centric activity-travel approach</u> is that the activity participation of children is primarily driven by the activity participation needs/responsibilities of adults (such as a parent having to go to the groceries, and tagging along her/his child for the grocery trip). And even if a serve-passenger activity is for the express purpose of enabling participation of a child in an activity, the implicit assumption is that it is the adults who decide on their children's activity participations. However, earlier studies in the child development field (Prinzie et al., 2008; Tackett et al., 2012; Tomasello, 2014) indicate that children as young as 5-6 years of age start developing their own identities and individualities, and social needs, and then interact with their parents and other adults to facilitate the fulfilment of these needs. This suggests a <u>child-centric activity-travel approach</u> that considers the characteristics of the child, while also using adult demographic and lifestyle variables (among other variables) as determinant variables. Of course, in reality, there is likely to be a combination of adult decision-driven children activities as well as child decision-driven adult activities leading up to the interactions between children and adult activity-travel patterns. This suggests a hybrid strategy of the adult-centric and child-centric approaches. While we leave the development of such a hybrid strategy for future efforts, in this paper, we focus on a more child-centric strategy as a means to shed more light on children-adult linkages.

1.1. Children's Extra-Curricular Activity Participation, Use of Active-Transport Modes, and the Geographical Context

As already discussed earlier, much literature regarding children's activity-travel patterns has focused on school activity-travel, and there is indeed a relatively good understanding in the literature of how children travel to school in a variety of geographical contexts, including but not limited to urban, rural, high-density, low-density, inner city, urban sprawl, etc. (see for example, amongst many others, Andersson et al., 2012; Fusco et al., 2012; Lang et al., 2011; Li and Zhao, 2015; Pojani and Boussauw, 2014; Rothman et al., 2018; Stark et al., 2018b; Zhang et al., 2017). However, studies on children's non-school activity-travel patterns have primarily been confined to the Western Hemisphere and generally in lower density urban environments where children are mostly dependent on automobiles for non-school activities (see, for example, Copperman and

Bhat, 2007; Sener and Bhat, 2007; Paleti et al., 2011; Fyhri and Hjorthol, 2009; Hjorthol and Fyhri, 2009; Stark et al., 2018a). Therefore, to fill this gap in research, the focus of this study lays upon children's non-school activity-travel patterns in a high density urban environment. Specifically, we focus on children's out-of-home (OH) activity participation beyond the usual school hours (henceforth, we will refer to such beyond-school time OH activities as "extra-curricular" activities) within the geographic locale of Hong Kong, where its compact and highly dense urban form means that distances are much more amenable to the active-travel modes of walking and cycling. At this junction, there are several important observations relating to childhood and children growing up in Hong Kong that ought to be considered, in relation to children's activities and travel behaviour, as summarized from Karsten (2014) and Loo and Lam (2015):

1) Hong Kong children are primarily raised in high-rise apartment buildings in compact residential neighbourhoods.
2) While there is a limited amount of public space, there are some playgrounds and recreational locations in urban areas for children to play in, although they reflect a "Chinese-style order" and lack in creativity.
3) Children as young as 2 years old start going to "school", and parents enrol their children into these playgroups and kindergartens early in order to get a head start in entering better primary schools.
4) Like many developed economies, Hong Kong is an ageing society and birth rates are low, but this does not seem to have restricted the competition for entering the best schools and the having the best "CV" of extra-curricular activities.

It is important to consider the above context when looking at children's activity-travel behaviour in Hong Kong. Children's participation in scheduled after-school extra-curricular activities are by far the norm rather than the exception in this part of the world (Karsten, 2014), although such scheduled activities are also gaining traction in the Western Hemisphere as well (Wheeler and Green, 2018; Molinuevo et al., 2010). Clearly, from a travel modelling perspective, a better understanding of children's extra-curricular activity participation (ECAP) can provide key insights into the downstream modelling of travel demand patterns of both children and adults. Furthermore, from a geographical perspective, the understanding of children's extra-curricular activities and related travel with respect to the neighbourhood environment will be helpful to inform policy in the planning and maintaining of communities that are compact, walkable and have a variety of destinations and activity venues for children and adults to frequent.

An important activity-travel dimension to the ECAPs of children, then, is the means by which children travel to these participations, especially in places such as Hong Kong where children have more options to use active-travel modes. Being able to safely walk or cycle to activity locations allow children to experience individual mobility and gain a certain degree of independence that may facilitate additional ECAP. At the same time, since active transport involves non-motorized modes, it can significantly reduce various negative transport externalities (notably traffic congestion, carbon emissions and particulate matter emissions, and traffic fatalities) because of the reduced need for parents to drive their children (Loo and Banister, 2016; Loo and Tsoi, 2018). Further, a good understanding of what facilitates or reduces the use of active-travel modes in childhood does not only help promote the use of such modes during childhood, but also potentially reduces motorized travel demand in the future because the use of active-travel modes as a child translates into a higher likelihood of walking and bicycling even in adulthood (Yang et al., 2014; Craigie et al., 2011). More broadly, engagement in extra-curricular activities and active transport can shape a child's future behaviour as a traveller (and as a citizen in general). Also, due to the discretionary nature of extra-curricular activities, and the intrinsic physical energy/capability of the youth population, it is natural to jointly examine children's extra-curricular activity participation (ECAP) and active-travel (ACT) choices. In this regard, although there have been some models that have analysed children's ECAP (Reisner, 2003; Sener et al., 2008; Paleti et al., 2011) and some others have studied children's ACT choices (Roth et al., 2012; Kemperman and Timmermans, 2014), there has been no earlier attempt that we are aware of to develop a joint model of the inter-relationship between ECAP and ACT choices within the context of the relevant neighbourhood environment. This is despite descriptive studies that have indicated that, for example, participation in sports activities is positively associated with the use of active travel modes (De Meester et al., 2017), and the use of active-travel modes is associated with generally increased ECAP (Lehner-Lierz, 2003; Mapes, 2009).

This paper aims to demonstrate that this interaction of ECAP and ACT is in fact closely intertwined with the built environment, and should not be overlooked. Having a good mix and variety of destinations in the neighbourhood environment has been shown to be important for promoting walking behaviour (Giles-Corti et al., 2009; Loo et al, 2017). Furthermore, if there are activity venues nearby children's homes, children are able to make these journeys on foot and there would be no need for parents to provide transportation for children to travel to these venues (Hoefer et al., 2001). If these extra-curricular activity venues exist nearby and are within reach, it would be a reasonable option for parents to send their children to participate in these nearby extra-curricular activities. In other words, activity location and by extension how children travel to these locations should not be seen as merely a by-product of the extra-curricular activity choice, because they are a highly important part of the package in activity selection (Simpkins et al., 2013; Ivaniushina and Aleksandrov, 2015). From the above, it should be clear that ECAP, ACT and RL need to be investigated together in order to understand the geographical context of children's activity-travel behaviour, especially for extra-curricular activities, which deserves more attention in the literature. This brings in a third endogenous variable in our analysis -- residential location (RL), as captured by the population density of the tertiary planning unit neighbourhood of the child's residence.[1,2] We consider residential location as an endogenous variable to account for the possibility that RL, along with ECAP and ACT, are determined as a choice bundle, and to accommodate for any self-selection effects in the influence of RL on ECAP and ACT. For example, households that embrace a "green" lifestyle, or that are generically predisposed to a dynamic cultural experience, may consciously choose to locate themselves in high density neighbourhoods (because of the ability to access activity locations within very close proximity).

[1] Tertiary planning unit (TPU) boundaries are drawn by the Planning Department of the HK Government, and they cover the whole territory of Hong Kong. There are 289 TPUs as demarcated in the most recent Census in 2011, and population density was calculated based on that year.

[2] While the built environment can comprise many other neighbourhood attributes, residential density is a measure that is easy to quantify, understand, and interpret. Thus, while other measures such as walkability index, pedestrian-friendliness, transit connectivity and service, land use diversity, and access to destinations may be appealing, they are not as easily defined. Besides, there is ample evidence that the many measures of land-use are highly correlated with density (see, for example, Badoe and Miller, 2000 and Brownstone and Fang, 2014), leading to the extensive (and sole) use of density to characterize the built environment in many earlier studies (*e.g.*, Kim and Brownstone, 2013; Paleti et al., 2013; Cao and Fan, 2012; Bhat et al., 2016).

The children in these same households will also then be more intrinsically pre-disposed than their counterparts in less dense neighbourhoods to partake in, say, sports or art or music activities as well as in active-travel. If so, and if this endogeneity in residential location choice is ignored, the result will be an exaggeration of any positive effects of residential density on activity participation in sports/arts/hobbies and active-travel mode use.

1.2. A Conceptual Environment-People Choices Interaction Framework

Theoretically, our study contributes more broadly to child development considerations within a more holistic framework of children's overall life-satisfaction and wellbeing. Our conceptual framework, as shown in Figure 1, builds upon and integrates the conceptual models developed by Leung and Loo (2017) and Loo et al. (2017). It puts children's self-worth, well-being, and overall life satisfaction explicitly as the ultimate outcomes (shown by ovals toward the right in Figure 1). Following the multiscale environment geographical framework (Loo et al., 2017), sociodemographic factors and environment-activity-travel decisions are explicitly considered to investigate children's residential location (RL), extra-curricular activity participation (ECAP), and active-travel (ACT) behaviour. In the framework of Figure 1, RL is part of the "Built Environment" block, ECAP is part of the "Activity Participation" block, and ACT is part of the "Travel Behaviour" block.

The conceptual framework posits that socio-demographic characteristics (the left block of Figure 1) impacts the environment-activity-travel decisions (middle block of Figure 1, comprising the inter-relationships and joint choices among neighbourhood environment, activity participation, and travel behaviour decisions), as well as the ultimate child outcomes (right block of Figure 1, associated with a child's self-worth, wellbeing, and life satisfaction). As discussed in the above sections, the relationship between socio-demographic characteristics with activity participation, travel behaviour and neighbourhood environment has primarily been related to travel behaviour for school and its on-site activities (e.g. Andersson et al., 2012; Li and Zhao, 2015; Pojani and Boussauw, 2014; Rothman et al., 2018; Zhang et al., 2017), so the "Activity Participation" block also considers extra-curricular activities (non-school and out-of-home) in this inter-relationship, in order to build on the current growing literature in this area (e.g. Copperman and Bhat, 2007; Paleti et al., 2011). The importance of the relationship between socio-demographic characteristics with the ultimate child outcomes, including self-worth, wellbeing and life satisfaction, has also been clearly illustrated in recent literature (e.g. Bulanda and Majumdar, 2009; Castillo et al., 2011; Leung and Loo, 2017; Gómez et al., 2017), which justifies the inter-linkage between the left block and the right block in Figure 1.

Further, activity participation behaviour and travel behaviour impact the child's self-worth (as reflected by the arrow from the "activity participation" and "travel behaviour" boxes to the "child's self-worth" oval in Figure 1). By engaging in sports or art activities, children can trust their mental and physical abilities, and become more self-confident compared with those who are restricted to the regular school curriculum (Gunduz et al., 2017; Kniffin et al., 2015). Similarly, for example, by using active-travel modes, children can experience an enhanced sense of independence and accomplishment, and obtain a sense of being able to discover the environment on their own (Kytta et al., 2015; Leung and Loo, 2017).

Activity participation and travel behaviour clearly influence the child's well-being. For example, studies in education and child development suggest that ECAP may have life-long benefits for the child, including a positive effect on the development of students' achievement in core subjects (Schuepbach, 2015; Covay and Carbonaro, 2010). At the same time, the packed schedules and any structured ECAP activities also imply that there is less unstructured play time and "down-time" for children (Karsten, 2014; Holloway and Pimlott-Wilson, 2014), which can have detrimental effects on a child's well-being (Gray, 2011; Laird et al., 2014). In terms of travel behaviour influences on well-being, epidemiological research studies have now clearly established a link between active travel and health outcomes. For example, the choice of active travel modes correlates with reduced symptoms of anxiety and depression, fewer physician visits, and reduced dependence on medications for such chronic health conditions as coronary heart disease, stroke, and diabetes (see Saunders et al., 2013; Lubans et al., 2011; Jarrett et al., 2012). Bicycling and walking, when incorporated into a child's daily routine, increases the rates of caloric expenditure and reduces obesity. Indeed, it has been found that countries with higher rates of walking and bicycling have lower obesity rates than countries that have a higher level of car dependency, especially for children (Poitras et al., 2016 and Mitchell et al., 2017). For example, the obesity rate among children is about 19% today in Hong Kong relative to about 33% in the US (Lobstein et al., 2015). But, worldwide, obesity among children continues to increase over time in most countries, including Hong Kong and the US. The relationship between activity participation and travel behaviour should be clear from the above discussion, which shows how activity participation and travel behaviour can affect children's well-being in both psychological and physical domains.

Finally, the conceptual framework in Figure 1 shows the link between a child's self-worth (SW) and a child's well-being (WB), and finally the connection between child's SW/WB and the child's overall life satisfaction (as represented by the vertical arrows in the "child outcomes" block of Figure 1), completing the conceptual framework. Self-worth, wellbeing and life satisfaction are treated as they appear primarily because considerations of perceptions of self (self-worth) and moods in mobility-specific and activity-specific situations (wellbeing) are components of life satisfaction, which justifies the one-way inter-linkage between SW and WB, SW and life satisfaction, and WB and life satisfaction (see Schimmack et al., 2002). While the conceptual framework being tested in this study (as marked by asterisks in Figure 1) does not include the variables in the "child outcomes" block, it remains highly important to consider the implications of the interrelationships between the other blocks in Figure 1 and how these interrelationships may affect a child's SW, WB and life satisfaction, and while there has been some recent work on this front (Leung and Loo, 2017; Ramanathan et al., 2014; Romero, 2015), it evidently deserves far more attention.

1.3. Exogenous and Endogenous Variables

Within the context of the conceptual framework presented in the previous section, the current paper considers the socio-demographic characteristics of the child and her/his household as exogenous variables.

The endogenous variables correspond to a subset of choices from the environment-people choices interaction block, corresponding to RL (as characterized by residential density), ECAP, and ACT choices (marked with an asterisk in Figure 1). RL is characterized as a nominal variable in our analysis and modelled using a multinomial probit (MNP) structure with three alternatives: Low density (<35,000 pers/sq. km), medium density (35,000-70,000 pers/sq. km), and high density (>70,000 pers/sq. km). These were the density qualifications selected, as they are highly relevant especially in the Asian context where there are many cities with large and still increasing population sizes, Hong Kong being one of them, with highly compact and high-rise urban neighbourhoods.

ECAP is characterized by the participation decision of children (aged 5-12) over the course of a five-day Monday-to-Friday work week in each of four extra-curricular activity types (i.e. multi-day data), as well as the time allocated (in minutes) to those activity types with a positive participation decision (weekend day data was not collected in the data used in the current analysis, and extending the current empirical investigation to include ECAP over the weekend days remains a direction for future research). The four extra-curricular activity types considered are academics (including learning new languages and attending a tutorial school for math, science, or other subjects), sports (tennis, rugby, gymnastics, taekwondo, and any other organized physical activity), arts (including piano, dance, recitation, singing, orchestra, and painting), and interests/hobbies (including such non-physical activities as engaging in chess, lego, and magic play sessions, as well as service/religious pursuits such as charity work, adventure corps, boys/girl scouts, and church-related activities).[3] For presentation ease, we will refer to the last extra-curricular activity type simply as "hobbies" in the rest of this paper. In addition to the four ECAP activities, we also consider an "in-home" activity type to which all individuals assign a non-zero positive amount of time (including such an "outside" activity type in the analysis allows the possibility that some children do not partake in ECAP activities at all; for convenience, we will refer to this variable with five alternatives, including the in-home alternative, as ECAP, even though only the first four are the extra-curricular OH activity type alternatives). Travel time to OH activities is excluded from the time budget based on the activity-based travel demand modelling perspective that individuals determine their activity needs and time-use in activities, and then travel features during the step of scheduling the activities to fulfil the desired activity agenda (see Bhat et al., 2016, and Spissu et al., 2009, for other studies that use a similar approach of focusing on activity time-use and excluding travel time). The ECAP variable takes a multiple discrete-continuous (MDC) form because individuals can participate in multiple alternatives (activity types) within the same work week (e.g. 1 sport activity and 1 academic activity), investing positive continuous amounts of time to each activity type participated in (e.g. 3 hours of soccer, 2 hours of English tutorial school). To construct the "time budget" of the MDC variable, we consider a typical school schedule (roughly from 8:30 am to 3 pm in Hong Kong) in which children have approximately six hours during each weekday to spend in ECAP after school (the results were not very sensitive to alternative lengths of seven and eight hours of total budget). Thus, the total time budget over the course of the work week was constructed in our analysis as being equal to 30 hours (=6 hours per day*five days per week) minus the travel times of each child.

The third endogenous variable, ACT, is represented as a three-category nominal variable that reflects the intensity (in terms of percentage of total weekly travel time) of active travel (walking and bicycling). From the survey data (to be discussed in the next section), we are able to compute the total weekly travel time expended in ECAP and the amount of this total travel time attributable to active travel. Then, those who spend zero ECAP travel time in active travel are categorized under the "no active travel" nominal category, while those who spend all their ECAP travel time in active travel are categorized under the "all travel is active travel" nominal category (for ease, we will refer to this category as "all active travel"). The remaining children are grouped under the "some active travel" nominal category. Using a three-category nominal variable that describes total weekly active travel time for all activities allows readers to conceptualize children's activity-travel behaviour easier, as distinct categories, rather than having to consider the complexities of different trip time and travel mode for different activity types.

[3] The activity categories were chosen such that they provide sufficient amount of detail and variety in defining activities, while ensuring adequate sample sizes in each of the categories for model estimation.

Our joint model takes the form of a multiple-discrete continuous probit (MDCP) and multinomial probit (MNP) model system, in which a MDCP component – corresponding to ECAP– and two MNP components – corresponding to RL and ACT – are modelled together in a multivariate framework. The model considers common observed effects of individual and household factors on these three endogenous variables. For example, children from households with low income earnings (an observed socio-demographic variable in our analysis) may be more constrained to locate in neighbourhoods with high population density, spend less time in ECAP, and also engage more in active transport. As importantly, our joint model also considers and accommodates the effects of potential common unobserved individual-specific factors, such as lifestyle factors, that may influence multiple endogenous variables simultaneously. For instance, a family that is intrinsically dynamic with an active lifestyle (an unobserved factor) may deliberately locate in high density residential neighbourhoods that offer higher accessibility to activity locations, encourage children to invest substantial time in sports pursuits, as well as encourage the use of active travel modes.

Finally, after accommodating for common observed and unobserved factors that necessitate the joint modelling of the three variables, our model also allows recursive "causal" effects among the endogenous variables (in joint choice situations where one or more of the endogenous variables is a discrete nominal or an MDC variable or some other limited-dependent variable, bi-directional causal effects are not logically consistent, and a recursive decision structure needs to be specified (Maddala, 1983). In our empirical analysis discussed later, we tested alternative recursive structures, but the preferred one in terms of goodness of fit was also intuitive in that the long-term decision (RL) influences the medium-term decision (ACT), and both impact the short-term ECAP decision. The reader will note that our model is, however, a true joint model (and not a sequential system), because unobserved correlations across the three variables (RL, ECAP, and ACT) are explicitly considered.

2. ANALYTIC FRAMEWORK AND DATA

The joint model used in the current paper takes nominal variables as well as an MDC endogenous variable. It is specifically designed to model the "Environment-Activity-Travel Decisions" that is the middle block in Figure 1, namely the joint choices of and interrelationships between residential location (nominal variable, represented by three population density categories), travel behaviour (nominal variable, represented by three active travel intensity categories), and extra-curricular activity participation (multiple discrete-continuous variable, represented by a discrete activity type and continuous time use in the particular activity). The next section discusses the necessary technical specifications of the model structure in detail.

2.1. Model Structure

2.1.1. The Nominal Variables

Consider an individual facing a multi-dimensional array of nominal (unordered-response) choices. Let the cardinality of the multi-dimensional array be G (that is, there are G nominal unordered-response variables in the choice space), and let g be the index for the nominal variables (g = 1, 2, 3, …, G). In the empirical context of the current paper, G=2 (the nominal variables are level of RL and ACT). Also, let I_g ($I_g \geq 2$) be the number of alternatives corresponding to the g^{th} nominal variable and let i_g be the corresponding index (i_g = 1, 2, 3, …, I_g). Using a typical utility maximizing framework for the nominal variables, the utility for alternative i_g for the g^{th} nominal variable of individual q can be written as:

$$U_{qgi_g} = \boldsymbol{\beta}'_g \boldsymbol{x}_{qgi_g} + \tilde{\varepsilon}_{qgi_g}, \tag{1}$$

where $\boldsymbol{x}_{qgi_g}$ is a (K_g×1)-column vector of exogenous attributes as well as possibly the observed values of other endogenous nominal variables (introduced as dummy variables), $\boldsymbol{\beta}_g$ is a (K_g×1)-column vector of corresponding coefficients, and ε_{qgi_g} is a normal scalar error term. Vertically stack the vector of errors $\boldsymbol{\varepsilon}_{qg} = [(\varepsilon_{qg1},\ \varepsilon_{qg2},\ ...,\ \varepsilon_{qgI_g})']$ for each individual. We will assume that the $\boldsymbol{\varepsilon}_{qg}$ vector is identically and independently distributed across individuals with a variance-covariance matrix of $\boldsymbol{\Lambda}_g$ (note that we allow the individual scalar error terms ε_{qgi_g} to be non-identical and non-independently distributed across alternatives within an individual q). The size of $\boldsymbol{\varepsilon}_{qg}$ is $(I_g \times 1)$, and the size of $\boldsymbol{\Lambda}_g$ is $(I_g \times I_g)$. The model above may be written in a more compact form by defining the following vectors and matrices: $\boldsymbol{U}_{qg} = (U_{qg1}, U_{qg2}, ..., U_{qgI_g})'$ ($I_g \times 1$ vector), $\boldsymbol{x}_{qg} = (\boldsymbol{x}_{qg1}, \boldsymbol{x}_{qg2}, \boldsymbol{x}_{qg3}, ..., \boldsymbol{x}_{qgI_g})'$ ($I_g \times K_g$ matrix), and $\boldsymbol{V}_{qg} = \boldsymbol{x}_{qg}\boldsymbol{\beta}_g$ ($I_g \times 1$ vector). Then, $\boldsymbol{U}_{qg} \sim MVN_{I_g}(\boldsymbol{V}_{qg}, \boldsymbol{\Lambda}_g)$, where $MVN_{I_g}(\boldsymbol{V}_{qg}, \boldsymbol{\Lambda}_g)$ is the multivariate normal distribution with mean vector $\boldsymbol{V}_{qg}$ and covariance $\boldsymbol{\Lambda}_g$.

Next, let $\boldsymbol{u}^*_{qg} = \left(U_{qg2} - U_{qg1}, U_{qg3} - U_{qg1}, ..., U_{qgI_g} - U_{qg1}\right)'$ $[(I_g - 1) \times 1)$ vector] (so $\boldsymbol{u}^*_{qg}$ is the vector of utility differences taken with respect to the first alternative for nominal variable g). Now, for any nominal variable, the full covariance matrix $\boldsymbol{\Lambda}_g$ of the original error terms in the utilities is not identifiable. One approach to estimation, typically used in univariate multinomial probit models, is to take the difference of the utilities with respect to the first alternative (that is, consider the differenced utility vector $\boldsymbol{u}^*_{qg}$), and estimate the covariance matrix of $\boldsymbol{u}^*_{qg}$ after scaling the first diagonal term to one. Defining $\boldsymbol{M}_g$ as an $(I_g - 1) \times I_g$ matrix that corresponds to an $(I_g - 1)$ identity matrix with an extra column of –1's added as the first column, we may write:

$$\boldsymbol{u}^*_{qg} \sim MVN_{I_g - 1}\left(\boldsymbol{W}_{qg}, \boldsymbol{\Sigma}_g\right), \text{ where } \boldsymbol{W}_{qg} = \boldsymbol{M}_g \boldsymbol{V}_{qg} \text{ and } \boldsymbol{\Sigma}_g = \boldsymbol{M}_g \boldsymbol{\Lambda}_g \boldsymbol{M}'_g. \tag{2}$$

The discussion above focuses on a single nominal variable g. When there are G nominal variables, consider the stacked $\tilde{G} \times 1-$ vector $\boldsymbol{u}^*_q \left[\left(\boldsymbol{u}^{*\prime}_{q1}, \boldsymbol{u}^{*\prime}_{q2}, ..., \boldsymbol{u}^{*\prime}_{qG}\right)'\right]$, where $\tilde{G} = \sum_{g=1}^{G} (I_g - 1)$. One may write $\boldsymbol{u}_q^* \sim MVN_{\tilde{G}}(\boldsymbol{W}_q, \boldsymbol{\Xi})$, where $\boldsymbol{W}_q = \left(\boldsymbol{W}'_{q1}, \boldsymbol{W}'_{q2}, ..., \boldsymbol{W}'_{qG}\right)'$ and $\boldsymbol{\Xi}$ is a $\tilde{G} \times \tilde{G}$ matrix as follows:

$$\boldsymbol{\Xi} = \begin{bmatrix} \boldsymbol{\Sigma}_1 & \boldsymbol{\Sigma}_{12} & . & . & . & \boldsymbol{\Sigma}_{1G} \\ \boldsymbol{\Sigma}_{21} & \boldsymbol{\Sigma}_2 & . & . & . & \boldsymbol{\Sigma}_{2G} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \boldsymbol{\Sigma}_{G1} & \boldsymbol{\Sigma}_{G2} & . & . & . & \boldsymbol{\Sigma}_G \end{bmatrix} \tag{3}$$

The off-diagonal elements in $\boldsymbol{\Xi}$ capture the dependencies across the utility differentials of different nominal variables, the differential being taken with respect to the chosen alternative for each nominal variable.

2.1.2. The MDC Outcome

Next, consider the ECAP MDC outcome. Following Bhat (2005) and Bhat (2008), we assume that the decision maker q (a combination of the child and her/his parents in this case) maximizes time utility subject to a binding time budget constraint:

$$\max \tilde{U}_q(\boldsymbol{t}_q) = \sum_{k=1}^{K-1} \frac{\tau_k}{\alpha_k} \psi_{qk} \left(\left(\frac{t_{qk}}{\tau_k} + 1 \right)^{\alpha_k} - 1 \right) + \frac{1}{\alpha_K} \psi_{qK} (t_{qK})^{\alpha_K} \tag{4}$$

$$s.t. \sum_{k=1}^{K} t_{qk} = T_q \,,$$

where the utility function $\tilde{U}_q(\boldsymbol{t})$ is quasi-concave, increasing and continuously differentiable, $\boldsymbol{t}_q$ is the time investment vector of dimension $K\times 1$ with elements t_{qk} ($t_{qk} \geq 0$), τ_k, α_k, and ψ_{qk} are parameters associated with activity purpose k, and T_q represents the time budget (i.e. 30 hours over the course of the work week, as explained in section 1.3) of individual q for allocation among the K activity purposes (k=1,2,…,K). In our case, K is equal to 5 (academic, sports, arts, hobbies, and in-home activities). The utility function form in Equation (4) allows corner solutions (*i.e.*, zero consumptions) for activity purposes 1 through $K-1$ through the parameters τ_k, which allow corner solutions for these alternatives while also serving the role of satiation ($\tau_k > 0$: $k = 1, 2, ..., K-1$). On the other hand, the functional form for the final activity purpose (in-home activity purpose in our analysis) ensures that some time is invested in activity purpose K (activity purpose K is usually referred to as an *essential outside good* in the microeconomics literature; see Bhat, 2008).

The role of α_k ($\alpha_k \leq 1$) in Equation (4) is to capture satiation effects, with a smaller value of α_k implying higher satiation for activity purpose k. τ_k, in addition to allowing zero consumptions, controls satiation by translating consumption quantity, while α_k controls satiation by exponentiating consumption quantity. Empirically speaking, it is difficult to disentangle the effects of τ_k and α_k separately, which leads to serious empirical identification problems and estimation breakdowns when one attempts to estimate both parameters for each good. Thus, Bhat (2008) suggests estimating a τ-profile (in which $\alpha_k \to 0$ for all alternatives, and the τ_k terms are estimated) and an α-profile (in which the τ_k terms are normalized to the value of one for all alternatives, and the α_k terms are estimated), and choose the profile that provides a better statistical fit.

The term ψ_{qk} in Equation (4) represents the stochastic baseline marginal utility for alternative k and individual q; that is, it is the marginal utility at the point of zero time investment for alternative k for individual q. The utility function in Equation (4) constitutes a valid utility function if, in addition to the constraints on the τ_k and α_k parameters, as discussed above, $\psi_{qk} \geq 0$

for all k and q. To ensure this condition, ψ_{qk} is parametrized as an exponential function of exogenous variable vector $\tilde{\boldsymbol{z}}_{qk}$ and a random error term as follows:

$$\psi_{qk} = \exp(\tilde{\boldsymbol{z}}_{qk}, \tilde{\xi}_{qk}) = \exp(\boldsymbol{\delta}' \tilde{\boldsymbol{z}}_{qk} + \tilde{\xi}_{qk}) \quad \text{or} \quad \bar{\psi}^{*}_{qk} = \ln(\psi_{qk}) = \boldsymbol{\delta}' \tilde{\boldsymbol{z}}_{qk} + \tilde{\xi}_{qk}, \tag{5}$$

where $\tilde{\boldsymbol{\delta}}$ is a column vector of coefficients and $\tilde{\xi}_{qk}$ captures the idiosyncratic characteristics that impact the baseline utility of individual q and activity purpose k. We assume that the error terms $\tilde{\xi}_{qk}$ are multivariate normally distributed across alternatives: $\tilde{\boldsymbol{\xi}}_q = (\tilde{\xi}_{q1}, \tilde{\xi}_{q2}, ..., \tilde{\xi}_{qK})' \sim MVN_K(\boldsymbol{0}_K, \tilde{\boldsymbol{\Omega}})$. But only differences in the logarithm of the baseline utilities matter, not the actual logarithm of the baseline utility values (see Bhat, 2008). Thus, it will be easier to work with the logarithm of the baseline utilities of the first $K-1$ alternatives, and normalize the logarithm of the baseline utility for the last alternative to zero. That is, we write:

$$\begin{aligned}
\bar{\psi}_{qk} &= \bar{\psi}^{*}_{qk} - \bar{\psi}^{*}_{qK} = \boldsymbol{\delta}'(\tilde{\boldsymbol{z}}_{qk} - \tilde{\boldsymbol{z}}_{qK}) + (\tilde{\xi}_{qk} - \tilde{\xi}_{qK}) \\
&= \boldsymbol{\delta}' \boldsymbol{z}_{qk} + \xi_{qk}, \ \boldsymbol{z}_{qk} = \tilde{\boldsymbol{z}}_{qk} - \tilde{\boldsymbol{z}}_{qK}, \ \xi_{qk} = (\tilde{\xi}_{qk} - \tilde{\xi}_{qK}) \ \forall k \neq K \\
\bar{\psi}_{qK} &= \bar{\psi}^{*}_{qK} - \bar{\psi}^{*}_{qK} = 0 \text{ for } k = K.
\end{aligned} \tag{6}$$

It should be clear from above that only the covariance matrix, say $\boldsymbol{\Omega}$ of the error difference vector $\boldsymbol{\xi}_q = (\xi_{q1}, \xi_{q2}, ..., \xi_{q,K-1})$, where $\xi_{qk} = (\tilde{\xi}_{qk} - \tilde{\xi}_{qK})$, is estimable, and not the covariance matrix $\tilde{\boldsymbol{\Omega}}$ of the original error terms (equivalently, only the covariance matrix $\boldsymbol{\Omega}$ of $\bar{\boldsymbol{\psi}}_q = (\bar{\psi}_{q1}, \bar{\psi}_{q2}, ..., \bar{\psi}_{q,K-1})$ is estimable, not the covariance matrix of $\bar{\boldsymbol{\psi}}^{*}_q = (\bar{\psi}^{*}_{q1}, \bar{\psi}^{*}_{q2}, ..., \bar{\psi}^{*}_{q,K-1})$). Further, because the sum of the time investments across activity purposes is equal to the total time budget, an additional scale normalization needs to be imposed in the general model of Equation (4) (see Bhat, 2008). A convenient normalization is to set the first element of $\boldsymbol{\Omega}$ (that is, $\boldsymbol{\Omega}_{11}$ to one). Further, for ease in interpretation of the covariance matrix $\boldsymbol{\Omega}$, we assume that the error term of the "outside" alternative $\tilde{\xi}_{qK}$ is independent of the error terms of the "inside" alternatives $\tilde{\xi}_{qk}$ $(k = 1, 2, ..., K-1)$. With this assumption, each covariance matrix element of $\boldsymbol{\Omega}$ can then immediately be interpreted as a direct indicator of the extent of variance and covariance in the utilities of the inside alternatives.[4]

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[4] In particular, assume that the variance of $\tilde{\xi}_{qK}$ is 0.5. Then, to normalize $\boldsymbol{\Omega}_{11}$ to one, we should have that the variance of $\tilde{\xi}_{q1}$ is also 0.5. Let the variance of $\tilde{\xi}_{qk}\,(k \neq 1, K)$ be σ_k^2 and the covariance between $\tilde{\xi}_k$ and $\tilde{\xi}_{k'}\,(k, k' = 1, 2, 3, \ ..., \ K-1; \ k \neq k')$ be $\sigma_{kk'}$. Then, the matrix $\boldsymbol{\Omega}$ of the error differences $\xi_{qk} = (\tilde{\xi}_{qk} - \tilde{\xi}_{qK})$ is:

$$\boldsymbol{\Omega} = \begin{bmatrix} 1 & 0.5+\sigma_{12} & 0.5+\sigma_{13} & \dots & 0.5+\sigma_{1,K-1} \\ 0.5+\sigma_{12} & 0.5+\sigma_2^2 & 0.5+\sigma_{23} & \dots & 0.5+\sigma_{2,K-1} \\ 0.5+\sigma_{13} & 0.5+\sigma_{23} & 0.5+\sigma_3^2 & \cdots & 0.5+\sigma_{3,K-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0.5+\sigma_{1,K-1} & 0.5+\sigma_{2,K-1} & 0.5+\sigma_{3,K-1} & \cdots & 0.5+\sigma_{K-1}^2 \end{bmatrix}$$

2.1.3. The Joint Model

Finally, to estimate the MDC variable and the nominal variables jointly, jointness is generated in the utilities of the differenced variables. Specifically, the covariance of $\boldsymbol{u}_q^*$ and $\bar{\boldsymbol{\psi}}_q$ can be written as:

$$\boldsymbol{\Gamma} = \begin{bmatrix} \boldsymbol{\Xi} & \boldsymbol{\Theta} \\ \boldsymbol{\Theta}' & \boldsymbol{\Omega} \end{bmatrix} \tag{7}$$

where $\boldsymbol{\Theta}$ captures the covariance between the vectors $\boldsymbol{u}_q^*$ and $\bar{\boldsymbol{\psi}}_q$. Assuming that the base utilities of the "low density" (for the RL choice) and "no active travel" (for the ACT choice) nominal categories, and the base utility preference for the "in-home" category of the ECAP MDC category, are independent of the utilities of all other non-base nominal/ECAP utilities, $\boldsymbol{\Theta}$ can be viewed as the covariance across the utilities of the non-base nominal categories and the non-base ECAP extra-curricular activities.

The model is estimated in GAUSS using the maximum approximated composite marginal likelihood (MACML) approach (Bhat, 2011), which is suitable for any context in which an MDC dependent variable and a nominal dependent variable are estimated jointly. This method of estimation is a simplification of the generalized heterogeneous data model (GHDM) proposed by Bhat et al. (2016), which in addition to nominal and MDC variables, estimates jointly count and ordinal variables.

2.2. The Data and Sample Description

The data used in this study were collected from a survey conducted at four primary schools between November 2015 and June 2016 in Hong Kong. In the survey, a child questionnaire was administered using a face-to-face interview approach by a team of research assistants. The interviews were held on-campus with select child participants aged five to 12 years of age. The participating children were also asked to bring home a parent questionnaire for one of their parents to fill in. Leung and Loo (2017) provide more details about the school and participant sampling methods. Detailed information about any weekly (from Monday to Friday, no weekend) extra-curricular activities of the children, including activity type, activity duration, travel time to activity, and travel mode to activity were obtained in the survey.

2.2.1. Sample Description

In this study, from the original raw data sample of 655 children, 103 were removed because of missing information on the endogenous variables of interest. The final sample comprises information on the residential locations and activity-travel patterns of 552 children.

Table 1 presents descriptive sample characteristics of the socio-demographic variables. Some interesting observations are as follows: (a) no specific age is dominant, though there are fewer five-year old and 12-year old children, (b) boys are over-represented relative to girls, (c) a majority of the parents have received post-secondary (beyond high-school) education (the education level of the parent corresponds to that of the parent who responds to the parent questionnaire), (d) more than a third of the households belong to the high income category (>59,999 HK$ per month), (e) as expected, motorized vehicle ownership in Hong Kong is much less than in the US and many other Western countries, (f) more than 70% of the families with children have at least two children, and (g) close to 60% of the children live in households in which both parents work, while over a third of children live in households where only the father works.

When compared with the statistics from the most recent census data (see final column of Table 1), as obtained from the Hong Kong Population By-census 2016 (CSD, 2018), our sample is skewed toward boys, children from households with highly educated parents, high household income, high motorized vehicle ownership, and children with one or more siblings (for some of the sociodemographic variables, comparable census information is not available and so is not provided in Table 1). The over-representation of children from households with multiple children (siblings) may be attributable to siblings attending the same school (Hui, 2015). Overall, however, the survey sample is not an unreasonable representation of Hong Kong's population of children between 5-12 years of age.

In terms of the endogenous variables, the distribution of children with respect to residential location (RL) is as follows: low density (48%; n = 265), medium density (24.6%; n = 136), and high density (27.4%; n = 151). The distribution of the other nominal variable of ACT (active travel) is as follows: no active travel (40.9%; n = 226), some active travel (28.1%; n = 155), and all active travel (31%; n = 171).

Table 2 provides the statistics on the ECAP MDC variable. The second and third numeric columns indicate the number (percentage) of individuals participating in each activity type and the mean duration of participation among those who participate, respectively. All children participate in in-home activities during the work week, as may be observed from the last row of the table. The mean duration in in-home pursuits exceeds 25 hours. Among the out-of-home (OH) extra-curricular activities, children participate most in academic and sports activities, and the least in hobbies. However, conditional on participation, the average duration of participation is highest in the academic purpose (exceeding three hours), and lowest in the arts activity purpose (an average of a little more than an hour and a half). These descriptive statistics suggest a relatively high baseline utility preference for the academic and sports activity purposes, and a clear high satiation for the arts activity purpose. The last two columns in Table 2 indicate the split between solo participations and multiple activity participations. For the first four activity purposes, solo participation implies individual participation in only that activity purpose, in addition to the in-home activity purpose, while multiple activity participation refers to participation in at least one other of the four OH extra-curricular activity purposes. For the in-home activity purpose, solo participation corresponds to participation in only in-home activities (no extra-curricular activity participation outside the home), while multiple activity participation refers to participation in in-home as well as at least one extra-curricular activity outside the home. Thus, the number for the "academic" activity purpose indicates that, of the 269 children participating in this activity purpose, 62 (or 23%) participated only in academic activity and in-home activity during the work week, and 207 (or 77%) participated in academic activity, in-home activity, and at least one of the remaining three extra-curricular activity purposes. Other numbers and percentages can be similarly interpreted. The main take-away is that there is a substantial amount of participation in multiple extra-curricular activity purposes during the work week, necessitating the use of our MDC framework for modelling the ECAP variable.

3. RESULTS

This section presents an overview of the model estimation results. A number of model specifications were tested, and variables were carefully introduced or excluded based on considerations of behavioural intuition and statistical significance. For the ECAP MDC mode component, the τ -profile (in which $\alpha_k \to 0$ for all alternatives, and the τ_k terms are estimated) was found to offer a better statistical fit in this study.

Table 3 shows the estimated coefficients for the final utility function specifications. The effects of exogenous variables (that is, the socio-demographic variables) on the utility of alternatives (that is, the estimates of the $\boldsymbol{\beta}_g$ vector elements on exogenous variables) for the nominal variables RL and ACT, and the effects of exogenous variables on the baseline preference (that is, the estimates of the $\boldsymbol{\delta}$ vector elements on the exogenous variables), are presented in the next section, corresponding to the linkage between the variables in the "Socio-demographic Characteristics" block with the "Environment-Activity-Travel Decisions" block in Figure 1. Then, the endogenous effects (that is, the estimates of the $\boldsymbol{\beta}_g$ and $\boldsymbol{\delta}$ vector elements corresponding to the endogenous variables) are presented in Section 3.2, which corresponds to the joint modelling of the "Environment-Activity-Travel Decisions" block in our conceptual framework in Figure 1. This is followed by the satiation parameters (the τ_k terms in the ECAP MDC model) in Section 3.3, as well as the estimates of the $\boldsymbol{\Gamma}$ covariance matrix in Section 3.4. Sections 3.5 and 3.6 present information on likelihood and non-likelihood measures of fit, respectively. In the context of Figure 1, Section 3.3 provides more specific detail about the ECAP block, while Sections 3.4-3.6 provide the empirical support by illustrating the superiority of our joint model, corresponding to the joint choices of the "Environment-Activity-Travel Decisions" block, being influenced by the exogenous variables in the "Socio-demographic Characteristics" block, and in turn influencing the "Child Outcomes" block (an independent model not considering RL, ECAP and ACT jointly would fail to address unobserved factors such as residential self-selection effects).

3.1. Effects of Exogenous Variables

The first row in Table 3, provides the estimates of the alternative specific constants, which do not have any substantive interpretations because of the presence of the age continuous variable. For the age variable, we examined alternative specifications, including a linear continuous specification, dummy variables for various age ranges, as well as a general piece-wise linear specification. Among these alternative specifications, the linear specification came out to be as good as the most non-linear dummy variable specification (corresponding to a dummy variable for each age) as well as a piece-wise linear specification, and is the one used in the final specification because of its parsimonious nature. The effects of the exogenous variables are now discussed in the same order as they appear in Table 3, corresponding to the linkage between the variables in the "Socio-demographic Characteristics" block with the "Environment-Activity-Travel Decisions" block in Figure 1.

AGE: The age of the child has no impact on residential location, but older children (relative to younger children) have a higher baseline preference for participating in (and, consequently, also higher durations of time-use, conditional on participation in) extra-curricular activities. This is to be expected, as children develop more independence as they grow older and parents are more likely to allow their children to be away from home for longer periods of time (Schoeppe et al., 2018). For similar reasons, older children are more likely than younger children to partake in active travel, especially because of their better ability to navigate traffic safely as a pedestrian or bicyclist. Parents' perceptions of the neighbourhood traffic situation or "stranger danger" seem to be at play here, and it would be sensible to target improving the neighbourhood environment and social cohesion attributes to have a community that is all-inclusive and friendly for families with young children (Schoeppe et al., 2018; Fyhri and Horthol, 2009; Francis et al., 2017).

GENDER: Girls, relative to boys, have a higher baseline preference for arts-related extra-curricular activities, suggesting gender-based variations in extra-curricular activity participation as encouraged by parents and societal norms. A similar result has also been observed in earlier studies with respect to the higher participation of girls in music, dance-related, and other artistic pursuits (see Sweeting and West, 2003, Mello and Worrell, 2008, and Holloway and Pimlott-Wilson, 2014). However, unlike these earlier studies that have consistently indicated a higher participation of boys in sports-related activities, no variations were found in our analysis between boys and girls in sports participation, pointing to a more gender-neutral encouragement of sports participation in Hong Kong relative to the US and other Western nations. Perhaps factors transcending traditional gender roles may be at play here, such as parental support for participation in sport activities for healthy physical development of their children regardless of gender (Leung et al., 2017), which calls for future literature to consider a more nuanced understanding of activities with respect to gender in the modern day. However, similar to results in the Western world, girls do still tend to spend less time in active travel to activities, presumably because of parents' rather asymmetric concerns for a daughter's vulnerability to social dangers (including road safety issues when walking or bicycling) relative to that of a son (see Mitra and Buliung, 2012). Besides, earlier transportation studies have identified a higher safety consciousness and motorized traffic-associated risk perception (to pedestrians and bicyclists) in girls relative to boys (see Kamargianni et al., 2015 and Bhat et al., 2015). Ultimately then, it seems that Hong Kong is still quite deeply rooted as a traditional patriarchal society (Karsten, 2014, and Liong, 2017), and the gender differences found suggest that these traditions do influence parents' decisions on children's extra-curricular activities (Simpkins et al., 2010), and they further seem to play a large part in the different upbringing and behaviour in boys and girls. Targeted efforts to improve arts participation in boys and active travel to activities in girls could be considered.

PARENT'S EDUCATION LEVEL: A high (post-secondary) educational level of the responding parent (undergraduate or graduate studies) increases the probability of the household to reside in a high density area. Highly educated individuals tend to be more likely to have a green lifestyle (see Franzen and Vogl, 2013), because individuals with a higher education are better able to assimilate environmental information quickly, and are more self-aware of the negative consequences of degrading the environment (such as the resulting health-related problems and global warming). And a green lifestyle also positively affects residence in high density neighbourhoods with better access to transportation modes other than solo auto, like public transit, walking, etc. (see, for example, de Abreu e Silva et al., 2012, and Bhat, 2015). The results also reveal a positive effect of parental education on children's participation in more activities after school (specifically academic and arts-related activities), and this has also been observed in the literature (see, for example, Pew Research Center, 2015; Bray and Kwok, 2003; Hjorthol and Fyhri, 2009). Overall, children in households with highly educated parents/guardians tend to locate in denser neighbourhoods and participate more in academic and "high culture" arts activities, most conceivably because they are better able to access these types of activities and activity centres in high-density areas (Karsten, 2014), and also because these parents/guardians may have higher expectations of their children and as a result arrange their children to participate more in these extra-curricular activities for their future all-rounded, whole person development (Bray and Kwok, 2003).

HOUSEHOLD INCOME: Lower income households appear to be less likely to reside in higher density areas relative to higher income households, perhaps a reflection of not being able to afford homes in urban locations. Chiu (2007) provides a detailed overview of public and private housing in Hong Kong, and notes that, while most Hong Kong housing developments are high-rises, government-sponsored housing for lower-income households are usually in the urban periphery and new towns, where residential density is relatively lower. Higher income households, on the other hand, are more likely to be living in newer, higher density multi-tower private developments in urban areas. Our model results also show that children living in lower income households (household monthly income of <HKD 30,000) tend to participate less in extra-curricular activities in general (as can be observed from the many negative coefficients on the income variable in the ECAP model component of Table 3). This effect of income is intuitive, because lower incomes constrain the money budget that can be allocated for extra-curricular activities, while higher incomes provide not only the financial wherewithal to indulge, but an explicit show of indulgence may be viewed as a socio-cultural vehicle to signal wealth, power and status, and privileged access to limited resources (de Castro and de Guzman, 2014). Interestingly, the income effect is confined to non-academic activity participation, but not academic extra-curricular activity participation. This seems indicative of the widespread ubiquity of academic activities among children across households of different walks of life. These academic activities correspond mainly to tutorial or revision classes at so-called "cram schools", and would only typically require a room with some tables, chairs and stationery. They are commonplace all around Hong Kong, and will likely become even more accessible and affordable in the future, as a consequence of various sociocultural factors such as expectations from the family, peer pressure and media culture (Yung and Bray, 2016).

PRESENCE OF MOTORIZED VEHICLES: We do not consider the presence of motorized vehicles as an explanatory variable of residential location, because motorized vehicle ownership is likely to be co-determined with residential location. This inter-dependence and jointness has been shown in many previous studies, including those by Paleti et al. (2013), Bhat et al. (2013), and Bhat et al. (2016). In terms of the effects of motorized vehicle ownership on children's ECAP, the results show that children living in households with 1 or more motorized vehicles tend to participate more in (and allocate more time to) extra-curricular activities (in particular, sports and hobbies) than children living in households without motorized vehicles. This is to be expected, because motorized vehicle ownership increases the activity "reach" of children (Karsten, 2014; Holloway and Pimlott-Wilson, 2014, Astroza et al., 2018). Further, the ubiquity of locations for academic and arts pursuits in Hong Kong makes the trip distances shorter for these kinds of activity participations (facilitating participation by non-motorized modes of transportation and public transport), while trip distances for sports and hobbies are longer (making it more difficult to participate in sports and hobbies using non-motorized modes and public transport). This is also observed in the fact that, while about 55-65% of trips to academic and arts pursuits are undertaken by active travel, the percentage drops to about 47% for sports and hobbies. Finally, as expected, motorized vehicle ownership has a negative impact on active travel, as also found in Copperman and Bhat (2007) and Bhat et al. (2015).

PRESENCE OF SIBLINGS: The presence of one or more siblings has no statistically significant impact on residential choice and active travel, but does affect ECAP. In particular, a child with a sibling in the household has a higher baseline preference for (is more likely to participate in, and spend more time in) academic and sports activities. This may be because academic and sports activities (such as a tutorial class or a tennis lesson or soccer practice) lend themselves more easily to group participation (allowing siblings to participate together, and also making it easier for parents to drive multiple children to extra-curricular activities) (see for example, Allbaugh et al., 2016; Price et al., 2017). Art/music-related activity (such as piano or violin lessons), on the other hand, tend to be one-on-one and hobby pursuits can be rather individual-specific as well, which may be why the effect for these activity types are not as apparent in terms of sibling presence.

WORKING STATUS OF PARENTS: In our analysis sample, only 14 children (less than 3% of all children) were living in households with only a single parent. That is, almost all children live in households with both parents. Further, only 12 children lived in households with no parent working outside the home. Thus, to consider the working status of parents, we used a simple dummy variable representing whether both parents (in dual-parent households) were working or not. The base category represents dual-parent households with only one parent working as well as the very small percentage of single-parent households and/or dual-parent households with none of the parents working. But, given the dominance of dual-parent households with only one parent working in the base category, we will interpret the results of the working status dummy variable simply as a distinction, within dual-parent households, between both parents working versus only one of the parents working. The results indicate that, if both parents work outside the home, then the household is more likely (relative to only one parent working) to reside in high-density locations rather than low-density locations. The preference of families with both parents working to live in the primary city may be a reflection of the benefits of knowledge spillovers (through formal and informal personal interactions) that occur in dense urban regions, and that provide and allow workers to retain (and enhance) their competitive edge in the market place (see Autant-Bernard and LeSage, 2011). Additionally, children living in households with both parents working appear to be less likely to partake in active travel relative to their peers in households with only one parent working. Perhaps non-working parents are willing to spend the additional time investment (relative to driving) involved in walking/bicycling when accompanying their children to extra-curricular activities, while children with dual-working parents are more likely to be driven to activities because of the time constraints on the working parents.

3.2. Endogenous Effects

A number of different directions of recursive endogenous effects were tested, but the preferred one corresponds to the long-term residential location decision (RL) influencing the medium-term decision (ACT), and both of these impacting the short-term ECAP decision. This corresponds to the joint modelling of the "Environment-Activity-Travel Decisions" block in our conceptual framework in Figure 1.

At least three observations may be made from Table 3 regarding endogenous effects. First, children living in households located in medium- or high-density neighbourhoods are more likely to participate in sports and arts activities (in comparison to children living in low density neighbourhoods), presumably because they are more conveniently located to access a greater range of activity/ recreation locations (such as parks, museums, and community centres). This result is consistent with the studies of Ding et al. (2013) and Born et al. (2014), both of which identify proximity to activities (such as parks and exercise facilities) as promoters of physical activity and leisure. This finding has important implications in a geographical and urban planning context, because the association of higher density neighbourhoods with more activity participation can potentially inform policymakers on the planning of where to locate future activity/ recreation venues for the greatest benefit of children and adults alike.

Second, higher density living is also related to higher levels of use of active transport by children to access extra-curricular activities. This impact may be attributed to higher densities being strongly correlated with better walk and bicycle infrastructure, as well as higher density areas providing more activity opportunities in close proximity that can be travelled to by active transport. Indeed, earlier time-use and physical activity studies, such as McCormack et al. (2014) and Sallis et al. (2016) indicate that higher density increases time spent in neighbourhood physical activity (primarily walking). Once again, this finding is highly beneficial for policymakers to design and maintain compact and walkable communities with a healthy mix of land uses (Loo et al, 2017).

Third, children who partake in active transport to access extra-curricular activities are more likely than their peers to spend time in sports activities. This complementary tendency between active transport use and active physical activity in recreational pursuits has been observed by Copperman and Bhat (2007) and Stewart et al. (2017) too. This finding provides evidence that greater after-school sport time use and active travel to activities may reinforce one another, which provides support for parents and educators to act as role models and further promote a physically active lifestyle among children, in order for children to develop and maintain these healthy habits as they grow up into teenagers and young adults (Yang et al., 2014; Craigie et al., 2011).

3.3. Satiation Parameters

The τ_k satiation parameters are presented in the last row of Table 3, and provides more specific detail about the ECAP block in the context of Figure 1. Satiation for a specific extra-curricular activity purpose k (k=1,2,…,K–1) increases as τ_k gets closer to zero. τ_k is not relevant for the in-home activity in the τ-profile because the in-home activity is always participated in, but satiation in the in-home activity is accommodated because as $\alpha_K \to 0$, which implies that the utility contribution of the in-home alternative, $\frac{1}{\alpha_K}\psi_{qK}(t_{qK})^{\alpha_K}$, in Equation (4), gets transformed to a non-linear utility term $\psi_{qK}\ln(t_{qK})$. As expected initially from the descriptive statistics, the extra-curricular arts activity in Table 3 has the highest satiation rate (lowest value of τ_k at 1.641). The high satiation rate for the arts activity means that participating in a shorter time period is already enough to achieve the same utility as compared with the other activity types. The satiation rates for the other extra-curricular activities are not as high as the arts activity, but in a similar range. This finding shows that arts activities do not usually last too long, in comparison with academic or sports activities. A musical instrument lesson would typically last around one hour, and meet once a week, whereas sporting practice or tutorial classes could conceivably last anywhere from one to three hours per session, and there may be more than one session per week. This is why we consider duration as well as activity type in children's ECAP, because considering activity type alone would remove the important details relating to time use and lead to a poorer and less accurate modelling framework.

3.4. Variance-Covariance Matrix of the Error Terms

Table 4 presents the estimated covariance matrix $\mathbf{\Gamma}$ of the error terms in the joint model (only the lower diagonal elements are presented, because of the symmetric nature of the covariance matrix), where significant error correlations would be indicative of the presence of unobserved factors that need to be considered. Many different specifications were considered for this covariance matrix. Interestingly, the diagonal blocks of the matrix (corresponding to the covariance within alternatives for each of the RL, ECAP, and ACT model components) were not significantly different from diagonal values of one and covariances of 0.5. Thus, these are fixed in our estimation. The implication is that the original error terms in the vectors $\boldsymbol{\varepsilon}_{qg}$ (representing the utilities of alternatives within the RL choice and within the ACT choice) are identically and independently distributed (IID) of each other (for each of g=1 corresponding to the RL nominal choice and g=2 corresponding to the ACT nominal choice). Similarly, $\tilde{\xi}_{q1}, \tilde{\xi}_{q2}, ..., \tilde{\xi}_{qK}$ of alternatives of the ECAP MDC model component are IID of each other. This is a result that just happens to be in our case, and we would not know if this is the case or not unless we estimated a more general model that allows the error terms within each of the three model components to be non-identical and correlated.

From the results presented in Table 4, it can also be observed that there are some significant error correlations across the RL, ECAP, and ACT components (see the off-diagonal block of the matrix). In particular, there are common unobserved statistically significant correlation effects between the RL medium/high density utilities of the RL and the ECAP baseline utilities of arts activities (a covariance of 0.12 between the utility of the medium density alternative and the arts baseline utility, a covariance of 0.27 between the utility of the high density alternative and the arts baseline utility, and a covariance of 0.43 between the utility of the high density alternative and the hobbies baseline utility). One possible explanation is that neighbourhoods with high residential density are also key activity nodes with mixed land use that support specialized arts pursuits as well as diverse hobby activities for children to join. In addition, there is a positive statistically significant covariance (0.19) between the utilities of the RL high density alternative and the ACT "all travel is active travel" alternative, as well as positive statistically significant covariances between the ECAP sports baseline utility and the utility of the ACT "all travel is active travel" alternative. These findings lend support to the observations in Bhat et al. (2016) that adults in households with a green lifestyle (unobserved factor) tend to locate in high density neighbourhoods, are more likely to pursue sports-related activities, and also partake more in active travel. As the values and lifestyles of parents permeate to the children, children living in high density areas appear intrinsically more likely also to pursue sports-related activities and active transport. In other words, these findings show that when considering the effect of residential density on children's activity-travel behaviour, it is important to take into account these unobserved factors, or else risk overstating the effect of the neighbourhood environment.

3.5. Likelihood Based Goodness of Fit Measures

So, does the joint model provide a better data fit? The joint and independent models may be compared using the adjusted composite likelihood ratio test (ADCLRT) statistic that is approximately chi-squared distributed (Bhat, 2011). The ADCLRT statistic value of comparison between the two models is 41.35. This value is higher than the chi-squared value corresponding to six degrees of freedom (based on the six covariance elements in Table 4) at the 0.05 level of statistical significance, which demonstrates the superior statistical fit of the joint model. Recently, Bhat (2018) demonstrated that the traditional likelihood-based tests for MDC models provides data fit only for the continuous values of consumption and, hence, a discrete consumption test is still needed. Following Bhat's (2018) likelihood form for the discrete consumption, we computed the predictive composite log-likelihood at convergence of the joint and independent models

(–11,277.38 and –11,491.02, respectively), considering only the discrete participation decision in the ECAP MDC model component. In this case, the ADCLRT statistic is 42.65, clearly indicating that the joint model is statistically superior to the independent model also in terms of the discrete event prediction.

3.6. Additional (Non-Likelihood Based) Goodness of Fit Measures

The likelihood-based tests (for the comparison of the independent and joint models) constitute disaggregate measures of fit that consider performance at the multivariate and disaggregate level. But, they are not the most intuitive. So, we also evaluate the performance of the two models intuitively and informally at an aggregate level through a heuristic diagnostic check of model fit by computing the predicted aggregate share of individuals for each multivariate outcome. In particular, we first compute the probability of each child participating in each of the 36 possible combinations of RL (three categories), ECAP (five categories), and ACT (three categories). The probabilities for each combination are averaged across individuals to obtain the predicted percentage of individuals falling into each combination category. The predicted probabilities are then compared with the actual percentage of children in each combination category using the weighted mean absolute percentage error (MAPE) statistic. To keep the presentation manageable, we confine our attention to the four out-of-home extra-curricular activities for the ECAP component and focus our results on the top ten combination categories of the resultant RL, ECAP, and ACT choices. The results are summarized in the top panel of Table 5. The first numerical entry indicates that 5.62% of the children in the sample live in a low-density neighbourhood, participate only in the extra-curricular sports activity, and engage in active travel. For that same multivariate combination, the joint model predicts a 4.65% share, while the independent model predicts a 4.12% share. Other numerical entries can be similarly interpreted. Overall, the MAPE values clearly indicate that the joint model does much better in prediction for any of the top 10 combinations listed in Table 5. Across all the ten combination categories, the weighted MAPE is about 60% higher for the independent model predictions (18.06 versus 29.12).

In the bottom panel of Table 5, we move beyond the discrete event predictions discussed in the last paragraph to present predictions for the continuous measure of the ECAP MDC variable (actual amount of allocated time). We do so by computing the percentage of the time-budget that is allocated to each of the extra-curricular activity purposes for children falling in a particular combination of residential density and active travel level. Again, only the statistics for the ten combinations with the highest time budget shares in the sample are summarized. Similar to the participation prediction case, the joint model provides a much better data fit (in comparison to the independent model) in the prediction of the actual amount of time spent in each activity type, no matter the density category and the level of active travel. Overall, the weighted MAPE is about 50% higher for the independent model predictions (15.17 versus 23.25). The above findings lend strong support to the employment of the joint model for this study, and justify our consideration of RL, ECAP and ACT as intertwined and fully integrated in the "Environment-Activity-Travel Decisions" block in the conceptual framework (Figure 1).

4. TREATMENT EFFECTS BASED ON RESIDENTIAL LOCATION CHOICE

In this section, the joint model is used to assess the impact of residential location choice (the "treatment") on the children-related ECAP and ACT dependent variables (the "outcomes"). An important measure to do so is the Average Treatment Effect (ATE) (see Heckman et al., 2001), which provides the expected change in the share of each ECAP and ACT alternative for a random child if s/he were located in a specific residential density configuration i as opposed to another residential density configuration $i' \neq i$.

For the ECAP variable, we focus only on the participation dimension here and compute the ATE measure for the extra-curricular activity k (k=1,2,…,K–1) as follows:

$$\hat{\text{ATE}}_{ii'}^{k} = \frac{1}{Q}\sum_{q=1}^{Q}\left(\left[P(t_{qk} > 0 \mid a_{qi} = 1) - P(t_{qk} > 0 \mid a_{qi'} = 1)\right]\right) \tag{8}$$

where t_{qk} is the time spent by child q on the extra-curricular activity k and a_{qi} is the dummy variable taking the value '1' if child q resides in residential density category i. To compute the probability that $t_{qk} > 0$, we draw, for each child, 100 sets of 1000 realizations from a multivariate normal sampling distribution of estimated parameters and the distribution of the error terms involved. For each child, each set, and each realization, we use the forecasting algorithm of Pinjari and Bhat (2010) to predict time allocations and, then, for each child and each set, evaluate the share of the 1000 realizations that predicted $t_{qk} > 0$ for each of the two density categories involved. The treatment effect is then computed as in Equation (8) for each set, and the mean across all the 100 sets is computed as the final ATE effect and the standard deviation across the 100 sets is computed as the standard error estimate. The calculation of ATE effects are helpful not only to obtain insights regarding whether, and how much, neo-urbanist design measures impact activity- and travel-related behaviours in the local context (Bhat et al., 2016), but also to understand the differences between the joint and independent models, and which model formulation is superior.

For the ACT nominal variable, we compute the ATE measure as follows:

$$\hat{\text{ATE}}_{ii'}^{g} = \frac{1}{Q}\sum_{q=1}^{Q}\left[P(\text{active travel} = g \mid a_{qi} = 1) - P(\text{active travel} = g \mid a_{qi'} = 0)\right], \tag{10}$$

where g could be "no active travel", "some active travel", or "all active travel".

The ATE measures above can be computed for all the pairwise combinations of residential density categories. Here, we focus on the case when a household in the lowest density neighbourhood is transplanted to the highest density neighbourhood. Table 6 presents the estimated ATE values (and standard errors) for both the ECAP and ACT variables. The first four numeric rows of the table provide the ATE values with respect to each of the extra-curricular activity purposes. For example, the ATE point estimate for the joint model corresponding to academic activities indicates that the probability of participating in academic activities reduces, on average, by 0.018 (standard error of 0.002) if a child belonging to a random household is transplanted from the low residential density category location to the high residential density category. In other words, if 1000 random children are relocated from the low density neighbourhood to the high density neighbourhood, the point estimate indicates a reduction in academic activities by 18 participations during the course of the week. On the other hand, the corresponding ATE point prediction for the independent model is –0.022 (standard error of 0.001). Other ATE estimates may be similarly interpreted. As expected based on the results from Section 3.2.2, transplanting a child from a low density to a high density neighbourhood also increases the probability of participation in sports and arts, and reduces participation in hobbies. For all the four ECAP activity types, the magnitude of the ATE from the independent model is always higher than from the joint model.[5] The fundamental reason is the presence of common unobserved factors that influence children's ECAP participation and residential location choice (as discussed in Section 3.4). For instance, children of families who live in high residential density neighbourhoods are pre-disposed to higher sports participation than their peers living in lower residential density areas. That is, children of families who would like their children to participate in sports tend to locate themselves in high residential density areas. The independent model, because it ignores this tendency, attributes more of the difference in sports activity participation between children in low density and high density neighbourhoods to the density change, while the joint model controls for the unobserved residential self-selection effect to provide the "true" causal effect of residential density change on sports activity participation. Of course, the effects on any given activity purpose will depend on effects on other activity purposes, and so the unobserved covariance effects in Section 3.4 translate to differences in the ATE estimates for all activity purposes between the joint and independent models.

The bottom two rows of Table 6 provide the ATE effects for the "some active travel" and "all active travel" categories (note that we do not show the effects for the "no active travel" category, because the ATE effects for all three categories should sum to zero). Under the joint model, if a child belonging to a random household is shifted from the low residential density category location to the high one, the probability of "some active travel" increases by an average of 0.087 (standard error is 0.005) and the probability of "all active travel" increases by an average of 0.106 (standard error of 0.006).[6] Specifically, if 1000 random children are relocated from the low density neighbourhood to the high density neighbourhood, the point estimate indicates that 87 more children will use active travel for some (but not all) of their extra-curricular activities, and 106 children will use active travel to access all of their extra-curricular activities. Again, the independent model exaggerates this residential density change effect by predicting, for the same scenario, that 103 more children will start using active travel for some (but not all) of their extra-curricular activities and 122 children will use active travel to access all of their extra-curricular activities. The exaggeration by the independent model is because of the residential self-selection effect with respect to active travel. As discussed earlier in Section 3.4, households with a green lifestyle propensity may both locate in high density neighbourhoods (looking for compact neighbourhoods with easy access to public transportation, bike lanes, *etc*.) as well as participate more in active travel (using an alternative mode of transportation such as bike and walk). The independent model cannot disentangle this self-selection association between residential location and active travel from the "true" effect of residential location on active travel. To be precise, the independent model combines these two effects, resulting in the exaggerated ATE for "all active travel". The ATE also is exaggerated for the "some active travel", even though there is no covariance between "some active travel" and "high density location". This is simply because of coefficient effect changes (between the joint and independent models) resulting from the introduction of covariance terms in the joint model.

One can also quantify the magnitude of the spurious residential self-selection effect and the "true" residential effect. As just discussed, the independent model comingles both of these

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[5] The ATEs for all the four extra-curricular activity purposes (and both the independent and joint models) are highly statistically significant. The t-statistics for testing the differences in the ATE estimates between the two models are in the range of 1.7-2.2. Overall, the results show that, if self-selection effects are ignored, the result is exaggerated effects of densification.

[6] The ATEs again are all statistically significant. The t-statistics for testing the differences in the ATE estimates between the two models are in the range of 1.5-2.0.

effects, while the joint model estimates the "true" residential effect. Because the independent model consistently exaggerates the ATE, the "true" effect may be computed as a percentage of the joint model ATE relative to the independent model ATE, while the self-selection effect may be computed as the difference of the ATE of the two models as a percentage of the independent ATE. The last two columns of Table 6 indicate that unobserved self-selection effects are estimated, based on the point estimates, to constitute about 10-20% of the difference in the ECAP and ACT variables between low density and high density households, while "true" built environment effects constitute the remaining 80-90% of the difference. To summarize, the results do show that residential living density has important "true" effects on children's activity-travel behaviour, but that these effects are exaggerated when residential self-selection is ignored.

5. CONCLUSIONS

Although there is a recognition that children's activity schedules are closely interwoven with those of their parents, and determine overall household activity-travel rhythms, much of the earlier literature on children's activity-travel behaviour has been confined (from a topical standpoint) to school travel and (from a geographical standpoint) to the Western Hemisphere. In this paper, the substantive focus is on children's extra-curricular activities, and the geographic focus is on a high density urban environment in East Asia, specifically Hong Kong. A better understanding of children's extra-curricular activity and travel in such high density, walkable environments can provide key insights into the downstream modelling of travel demand patterns of both children and adults. Further, by focusing on extra-curricular activities as well as active transport of children, there is an opportunity to significantly reduce negative transport externalities, help promote active lifestyles during childhood, and shape a child's future behaviour as a traveller (and as a citizen in general). In addition, our study here also contributes more broadly to child development considerations within a more holistic framework of children's overall life-satisfaction and wellbeing.

This paper has offered a framework to understand children's extra-curricular activities time allocation and active travel participation in Hong Kong. Three variables of interest are considered: weekly time spent in four different types of out-of-home after-school activities (academic, sports, arts, and other), level of active travel, and residential location choice (based on residential density). The proposed model takes into account common observed and unobserved effects that can be affecting the three outcomes simultaneously.

The results indicate important demographic effects of the child on the child's extra-curricular activity participation and travel. Older children are more likely to partake in extra-curricular activities as well as active travel to these activities. Similar to many studies in the Western world, girls appear to be more likely than boys to participate in arts activities and less likely to walk/bicycle to activities. However, we did not find a statistically significant variation between boys and girls in sports participation, unlike multiple studies in the US and other Western nations that suggest higher a sports participation rate among boys. In addition to child demographics, family demographics also plays a role in children's activity-travel behaviour. Children in households with highly educated adults tend to participate more in academics and "high culture" arts activity opportunities, while those in lower income households tend to participate less in extra-curricular activities in general (except for academic pursuits). A high motorized vehicle ownership in a household promotes children's participation in sports, but also reduces active travel. The former effect may be attributable to the relatively long distances to travel to sports activities relative to other activities. Other results include the higher likelihood of children with siblings to participate in sports and academic activities, and a lower tendency of active travel among children with both parents working.

Overall, the findings show that children's activity and travel behaviour within the same city can differ quite substantially based on neighbourhood environment (notably residential density) and family socio-demographic background. The empirical findings and analysis provide insights for policy development. First, children with parents of lower socioeconomic status (SES, as determined by education and income earnings) and children with no siblings participate less in extra-curricular activities in general, and policies that particularly target these segments of children for promoting extra-curricular activities appear to be warranted. Since 2002, non-government entities in Hong Kong have made available, to children of lower SES, some financial assistance to facilitate participation in extra-curricular activities deemed beneficial to the child's "whole-person development" (EDB, 2018). The continuation and expansion of such a policy with higher funding amounts and a wider set of eligible extra-curricular activity purposes needs careful consideration. This is particularly so because a higher rate of participation in extra-curricular activities has been shown to be even more beneficial for children of lower SES status than their more privileged counterparts (Dumais, 2006; Kawashima-Ginsberg, 2014), and may provide key opportunities to meet new friends, learn to work as a team, develop social skills and fairness concepts, and develop positive character traits (Snellman et al., 2015). Second, the result regarding the lower active travel among children of dual-working parents suggest that time poverty effects are at play here; that is, time constraints make it difficult for parents to partake in activities with their children that provide relaxation, stress alleviation, and physical exercise, all of which contribute to both physical and mental well-being. At the same time, the share of dual-earner households in Hong Kong has risen in the past few decades, at least in part due to financial pressures of living in a high-cost city (HKCSS, 2013). The implication is that individuals in dual-earner households face a work-family conflict situation that permeates into their children's physical activity lifestyle, suggesting the need to rigorously evaluate and consider the implementation of work-friendly policies such as proportional wages for part-time work, flexible work scheduling, tele-working, and related government policies (see, for example, Goodin, 2010). Doing so may also be advantageous to employers because of a potential increase in job satisfaction and improved work productivity (see, for example, Choi, 2009 and Wong and Ko, 2009). To summarize, company policies designed to provide a sense of empowerment to employees to take care of personal and family situations can help instil a stronger sense of work-family balance that benefits the next generation of adults and society as a whole. Third, the effect of motorized vehicle ownership on children's activity-travel patterns, when combined with the effect of residential density, suggests that policies that encourage mixed-land use planning and compact development reinforce each other in increasing physical activity participation of children, both in the form of sports activity participation and utilitarian active travel to activity centres. Thus, mixed and compact development not only seems to be an instrument to reduce traffic congestion, energy dependence, and air pollution, but also an effective tool to promote an active lifestyle among children, with far-reaching public health benefits. Relatedly, our results also recommend that government-led and non-government-led initiatives, such as walking school buses and Safe Routes to School programs (see Walking School Bus, 2018, and Safe Routes to School, 2018), be continued to increase active travel between home, school, and after-school activities, especially in the higher density suburban and urban areas.

From a travel demand modelling standpoint, one of the limitations of current activity-based travel demand model systems is the inadequate attention and modelling of the activity patterns of children. Not only does this result in the absence of much needed policy information for promoting participation in extra-curricular activities and active lifestyle, as just discussed earlier, but it can also result in relatively inaccurate predictions of the activity-travel patterns of adults. In particular, the ability to model children's activity engagement (and the interactions between these engagements and those of adults) within larger activity-based travel model systems would offer a strong basis for forecasting travel in response to shifts in population demographics over time, or land-use and transportation policies. In this context, the model presented in this paper offers a framework for representing and analysing the activity-travel patterns of children within larger travel demand model systems.

In closing, this study represents a formulation and application of a joint econometric framework to examine household residential location choice, children's activity participation and time-use, and children's active lifestyle levels. Future research should further explore intra-household interactions as a priority area for undertaking time-use research, as part of a family-based activity-travel generation and scheduling process.

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REFERENCES

Allbaugh, C.N., Bolter, N.D., and Shimon, J.M. (2016). Influence on Physical Activity and Sport Participation: Considerations for Coaches, Strategies. *Strategies* 29(4), 24-28.

Andersson, E., Malmberg, B., and Östh, J. (2012). Travel-to-school distances in Sweden 2000–2006: Changing school geography with equality implications. *Journal of Transport Geography* 23, 35-43.

Astroza, S., Bhat, P.C., Bhat, C.R., Pendyala, R.M., and Garikapati, V.M. (2018). Understanding activity engagement across weekdays and weekend days: A multivariate multiple discrete-continuous modeling approach. *Journal of Choice Modelling*, forthcoming.

Autant-Bernard, C., and LeSage, J. (2011). Quantifying knowledge spillovers using spatial econometric models. *Journal of Regional Science* 51(3), 471-496.

Badoe, D.A. and Miller, E.J. (2000). Transportation–land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research Part D* 5(4), 235-263.

Bhat, C.R. (2005). A multiple discrete-continuous extreme value model: Formulation and application to discretionary time-use decisions. *Transportation Research Part B* 39(8), 679-707.

Bhat, C.R. (2008). The multiple discrete-continuous extreme value (MDCEV) model: Role of utility function parameters, identification considerations, and model extensions. *Transportation Research Part B* 42(3), 274-303.

Bhat, C.R. (2011). The maximum approximate composite marginal likelihood (MACML) estimation of multinomial probit-based unordered response choice models. *Transportation Research Part B* 45(7), 923-939.

Bhat, C.R. (2015). A new generalized heterogeneous data model (GHDM) to jointly model mixed types of dependent variables. *Transportation Research Part B* 79, 50-77.

Bhat, C.R. (2018). A new flexible multiple discrete-continuous extreme value (MDCEV) choice model. *Transportation Research Part B* 110, 261-279.

Bhat, C.R., Astroza, S., Bhat, A.C., and Nagel, K. (2016). Incorporating a multiple discrete-continuous outcome in the generalized heterogeneous data model: Application to residential self-selection effects analysis in an activity time-use behavior model. *Transportation Research Part B* 91, 52-76.

Bhat, C.R., Dubey, S.K., and Nagel, K. (2015). Introducing non-normality of latent psychological constructs in choice modeling with an application to bicyclist route choice. *Transportation Research Part B* 78, 341-363.

Bhat, C., Guo, J., Srinivasan, S., and Sivakumar, A. (2004). Comprehensive econometric microsimulator for daily activity-travel patterns. *Transportation Research Record* 1894, 57-66.

Bhat, C.R., Goulias, K.G., Pendyala, R.M., Paleti, R., Sidharthan, R., Schmitt, L., and Hu, H-H. (2013). A household-level activity pattern generation model with an application for Southern California. *Transportation* 40(5), 1063-1086.

Born, K., Yasmin, S., You, D., Eluru, N., Bhat, C.R., and Pendyala, R.M. (2014). Joint model of weekend discretionary activity participation and episode duration. *Transportation Research Record* 2413, 34-44.

Bray, M., and Kwok, P. (2003). Demand for private supplementary tutoring: conceptual considerations, and socio-economic patterns in Hong Kong. *Economics of Education Review* 22, 611-620.

Brownstone, D., and Fang, H.A. (2014). A vehicle ownership and utilization choice model with endogenous residential density. *The Journal of Transport and Land Use* 7(2), 135-151.

Bulanda, R.E., and Majumdar, D. (2009). Perceived Parent–Child Relations and Adolescent Self-Esteem. *Journal of Child and Family Studies* 18(2), 203-212.

Cao, X., and Fan, Y. (2012). Exploring the influences of density on travel behavior using propensity score matching. *Environment and Planning B* 39(3), 459-470.

Castillo, J., Welch, G., and Sarver, C. (2011). Fathering: The Relationship Between Fathers' Residence, Fathers' Sociodemographic Characteristics, and Father Involvement. *Maternal and Child Health Journal* 15(8), 1342-1349.

Chiu, R.L.H. (2007). Planning, land and affordable housing in Hong Kong. *Housing Studies* 22(1), 63-81.

Choi, S. (2009). Diversity in the US federal government: Diversity management and employee turnover in federal agencies. *Journal of Public Administration Research and Theory* 19(3), 603-630.

Christie, N., Kimberlee, R., Towner, E., Rodgers, S., Ward, H., Sleney, J., and Lyons, R. (2011). Children aged 9–14 living in disadvantaged areas in England: Opportunities and barriers for cycling. *Journal of Transport Geography* 19(4), 943-949.

Copperman, R., and Bhat, C.R. (2007). An exploratory analysis of children's daily time-use and activity patterns using the child development supplement (CDS) to the US panel study of income dynamics (PSID). *Transportation Research Record* 2021, 36-44.

Covay, E., and Carbonaro, W. (2010). After the bell: Participation in extracurricular activities, classroom behavior, and academic achievement. *Sociology of Education* 83(1), 20-45.

Craigie, A.M., Lake, A.A., Kelly, S.A., Adamson, A.J., and Mathers, J.C. (2011). Tracking of obesity-related behaviours from childhood to adulthood: A systematic review. *Maturitas* 70(3), 266-284.

CSD (2018). 2016 Population By-census. *Hong Kong SAR Government Census and Statistics Department*. Available at: https://www.bycensus2016.gov.hk/en/index.html. Retrieved Feb 27 2018.

De Abreu e Silva, J., Martinez, L., and Goulias, K. (2012). Using a multi equation model to unravel the influence of land use patterns on travel behavior of workers in Lisbon. *Transportation Letters* 4(4), 193–209.

De Castro, B.V., and de Guzman, A.B. (2014). From Scratch to Notch: Understanding Private Tutoring Metamorphosis in the Philippines From the Perspectives of Cram School and Formal School Administrators. *Education and Urban Society* 46(3), 287-311.

De Meester, A., Cardon, G., De Bourdeaudhuij, I., and Haerens, L. (2017). Extracurricular school-based sports as a stepping stone toward an active lifestyle? Differences in physical activity and sports-motivation between extracurricular school-based sports participants and non-participants. *Journal of Teaching in Physical Education* 36(4), 485-497.

Deka, D. (2013). An explanation of the relationship between adults' work trip mode and children's school trip mode through the Heckman approach. *Journal of Transport Geography* 31, 54-63.

Deka, D. (2017). Impacts of standardizing school start time on children and household workers – An examination with NHTS data. *Journal of Transport Geography* 59, 40-48.

Ding, D., Adams, M.A., Sallis, J.F., Norman, G.J., Hovell, M.F., Chambers, C.D., … and Bauman, A.E. (2013). Perceived neighborhood environment and physical activity in 11 countries: Do associations differ by country? *International Journal of Behavioral Nutrition and Physical Activity* 10, 57

Dumais, S.A. (2006). Elementary school students' extracurricular activities: The effects of participation on achievement and teachers' evaluations. *Sociological Spectrum* 26, 117-147.

EDB (2018). The Hong Kong Jockey Club Life-wide Learning Fund. *Hong Kong SAR Government Education Bureau*. Available at: http://www.edb.gov.hk/en/curriculum-development/major-level-of-edu/life-wide-learning/jc-fund/index.html. Retrieved Apr 2 2018.

Francis, J., Martin, K., Wood, L., and Foster, S. (2017). 'I'll be driving you to school for the rest of your life': A qualitative study of parents' fear of stranger danger. *Journal of Environmental Psychology* 53, 112-120.

Franzen, A., and Vogl, D. (2013). Two decades of measuring environmental attitudes: A comparative analysis of 33 countries. *Global Environmental Change* 23(5), 1001-1008.

Fusco, C., Moola, F., Faulkner, G., Buliung, R., and Richichi, V. (2012). Toward an understanding of children's perceptions of their transport geographies: (Non)active school travel and visual representations of the built environment. *Journal of Transport Geography* 20(1), 62-70.

Fyhri, A., and Hjorthol, R. (2009). Children's independent mobility to school, friends and leisure activities. *Journal of Transport Geography* 17(5), 377-384.

Ghekiere, A., Deforche, B., De Bourdeaudhuij, I., Clarys, P., Mertens, L., Cardon, G., … and Van Cauwenberg, J. (2018). An experimental study using manipulated photographs to examine interactions between micro-scale environmental factors for children's cycling for transport. *Journal of Transport Geography* 66, 30-34.

Giles-Corti, B., Kelty, S.F., Zubrick, S.R., and Villanueva, K.P. (2009). Encouraging Walking for Transport and Physical Activity in Children and Adolescents: How Important is the Built Environment? *Sports Medicine* 39(12), 995-1009.

Gómez, D.O., Casas, F., Inzunza, J.A., and Costa, P.A. (2017). School and Neighborhood: Influences of Subjective Well-Being in Chilean Children. In: J. Sarriera and L. Bedin (Eds.), *Psychosocial Well-being of Children and Adolescents in Latin America. Children's Well-Being: Indicators and Research* (Volume 16). Springer: Cham, Switzerland

Goodin, E. R. (2010). Temporal justice. *Journal of Social Policy* 39(1), 1-16.

Gray, P. (2011). The decline of play and the rise of psychopathology in children and adolescents. *American Journal of Play* 3(4), 443-463.

Gunduz, N., Keskin, M.T., and Erdugan, A. (2017). Investigation of participation motivations in exercises of students participating in archery in extra curricular activities. *Universal Journal of Educational Research* 5(10), 1764-1771.

Heckman, J., Tobias, J.L., and Vytlacil, E. (2001). Four parameters of interest in the evaluation of social programs. *Southern Economic Journal* 68(2), 210-223.

Hjorthol, R., and Fyhri, A. (2009). Do organized leisure activities for children encourage car-use? *Transportation Research Part A* 43(2), 209-218.

HKCSS (2013). She hui fa zhan zhuan ti zi liao: xiang gang er tong gai kuang [Theme of societal development: Overview of Hong Kong children]. The Hong Kong Council of Social Service. Available at: http://c4e.hkcss.org.hk/user/child201307.pdf. Retrieved Jun 14, 2018.

Hoefer, W.R., McKenzie, T.L., Sallis, J.F., Marshall, S.J., and Conway, T.L. (2001). Parental provision of transportation for adolescent physical activity. *American Journal of Preventive Medicine* 21(1), 48-51.

Holloway, S. L., and Pimlott-Wilson, H. (2014). Enriching children, institutionalizing childhood? Geographies of play, extracurricular activities, and parenting in England. *Annals of the Association of American Geographers* 104(3), 613-627.

Hui, W. T. (2015, November 12). Xiong di jie mei tong xiao [Siblings in the same school]. *Ta Kung Pao*, p. B21. Available at: http://paper.takungpao.com/resfile/PDF/20151112/PDF/b21_screen.pdf. Retrieved Feb 28, 2018.

Ivaniushina, V.A., and Aleksandrov, D.A. (2015). Socialization Through Informal Education: The Extracurricular Activities of Russian Schoolchildren. *Russian Education & Society* 57(4), 189-213.

Jarrett, J., Woodcock, J., Griffiths, U.K., Chalabi, Z., Edwards, P., Roberts, I., and Haine, A. (2012). Effect of increasing active travel in urban England and Wales on costs to the National Health Service. *The Lancet* 379(9832), 2109-2205.

Kamargianni, M., Dubey, S., Polydoropoulou, A., and Bhat, C.R. (2015). Investigating the subjective and objective factors influencing teenagers school travel mode choice–An integrated choice and latent variable model. *Transportation Research Part A* 78, 473-488.

Karsten, L. (2014). Middle-class childhood and parenting culture in high-rise Hong Kong: On scheduled lives, the school trap and a new urban idyll. *Children's Geographies* 13, 556–570.

Kawashima-Ginsberg, F. (2014). Harry, Hermione, Ron and Neville– Portraits of American teenagers' extracurricular involvement, and implications for educational interventions. *CIRCLE Working Paper #80*. Available at: https://civicyouth.org/wp-content/uploads/2014/03/WP_80_KawashimaGinsberg.pdf. Retrieved Jun 14, 2018.

Kemperman, A., and Timmermans, H. (2014). Environmental correlates of active travel behavior of children. *Environment and Behavior* 46(5), 583-608.

Kim, J., and Brownstone, D. (2013). The impact of residential density on vehicle usage and fuel consumption: Evidence from national samples. *Energy Economics* 40, 196-206.

Kim, S.-N., Choo, S., Mokhtarian, P.L. (2015). Home-based telecommuting and intra-household interactions in work and non-work travel: A seemingly unrelated censored regression approach. *Transportation Research Part A* 80, 197-214.

Kniffin, K.M., Wansink, B., Shimizu, M. (2015). Sports at work: Anticipated and persistent correlates of participation in high school athletics. *Journal of Leadership & Organizational Studies* 22(2), 217-230.

Kyttä, M., Hirvonen, J., Rudner, J., Pirjola, I., Laatikainena, T. (2015). The last free-range children? Children's independent mobility in Finland in the 1990s and 2010s. *Journal of Transport Geography* 47, 1-12.

Laird, S.G., McFarland-Piazza, L., and Allen, S. (2014). Young children's opportunities for unstructured environmental exploration of nature: Links to adults' experiences in childhood. *International Journal of Early Childhood Environmental Education* 2(1), 58-75.

Lam, W.W.Y., and Loo, B.P.Y. (2014). Determinants of children's independent mobility in Hong Kong. *Asian Transport Studies* 3(2), 250-268.

Lang, D., Collins, D., and Kearns, R. (2011). Understanding modal choice for the trip to school. *Journal of Transport Geography* 19(4), 509-514.

Lehner-Lierz, U. (2003). The role of cycling for women. *Sustainable Transport*, 123-143.

Leung, K.Y.K., and Loo, B.P.Y. (2017). Association of children's mobility and wellbeing: A case study in Hong Kong. *Travel Behaviour and Society* 9, 95-104.

Leung, K.-M., Chung, P.-K., and Kim, S. (2017). Parental support of children's physical activity in Hong Kong. *European Physical Education Review* 23(2), 141-156.

Li, S., and Zhao, P. (2015). The determinants of commuting mode choice among school children in Beijing. *Journal of Transport Geography* 46, 112-121.

Lim, K.-K. (2015). Modeling intra-household interactions in the generation of social-recreational tour. *KSCE Journal of Civil Engineering* 19(6), 1870-1881.

Liong, M. (2017). From Control to Care: Historicizing Family and Fatherhood in Hong Kong. In: *Chinese Fatherhood, Gender and Family: Father Mission*. Palgrave Macmillan: London, U.K.

Lobstein, T., Jackson-Leach, R., Moodie, M. L., Hall, K. D., Gortmaker, S. L., Swinburn, B. A., and McPherson, K. (2015). Child and adolescent obesity: Part of a bigger picture. *The Lancet* 385(9986), 2510-2520.

Loo, B.P.Y. and Banister, D. (2016) Decoupling transport from economic growth: Extending the debate to include environmental and social externalities. *Journal of Transport Geography* 57, 134-144.

Loo, B.P.Y., and Lam, W.W.Y. (2015). Does neighbourhood count in affecting children's journeys to schools? *Children's Geographies* 13(1), 89-113.

Loo, B.P.Y., Lam, W.W.Y., Mahendran, R. and Katagiri, K. (2017) How is the neighbourhood environment related to the health of seniors in Hong Kong, Singapore and Tokyo? Some insights for promoting ageing-in-place. *Annals of the American Association of Geographers* 107(4), 812-828.

Loo, B.P. Y. and K.H. Tsoi (2018) "The Sustainable Transport Pathway: A Holistic Strategy of Five Transformations." *Journal of Transport and Land Use* 11(1): 961-980.

Lopes, F., Cordovil, R., and Neto, C. (2014). Children's independent mobility in Portugal: Effects of urbanization degree and motorized modes of travel. *Journal of Transport Geography* 41, 210-219.

Lubans, D.R., Boreham, C.A., Kelly, P., and Foster, C.E. (2011). The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity* 8, 5.

Maddala, G.S. (1983). *Limited-Dependent and Qualitative Variables in Economics*. New York: Cambridge University Press.

Mapes, J. (2009). *Pedaling Revolution: How Cyclists are Changing American Cities*. Oregon State University Press, Oregon.

McCormack, G.R., Rock, M., Swanson, K., Burton, L., and Massolo, A. (2014). Physical activity patterns in urban neighbourhood parks: Insights from a multiple case study. *BMC Public Health* 14, 962.

McDonald, N.C. (2008). Household interactions and children's school travel: The effect of parental work patterns on walking and biking to school. *Journal of Transport Geography* 16(5), 324-331.

McDonald, N.C. (2012). Is there a gender gap in school travel? An examination of US children and adolescents. *Journal of Transport Geography* 20(1), 80-86.

Mello, Z. R., and Worrell, F. C. (2008). Gender Variation in Extracurricular Activity Participation and Perceived Life Chances in Trinidad and Tobago Adolescents. *Psykhe* 17(2), 91-102.

Mitchell, J.A., Dowda, M., Pate, R.R., Kordas, K., Froberg, K., Sardinha, L.B., and Page, A. (2017). Physical activity and pediatric obesity: A quantile regression analysis. *Medicine and science in sports and exercise* 49(3), 466.

Mitra, R., and Buliung, R.N. (2012). Built environment correlates of active school transportation: Neighborhood and the modifiable areal unit problem. *Journal of Transport Geography* 20(1), 51-61.

Molinuevo, B., Bonillo, A., Pardo, Y., Doval, E., Torrubia, R. (2010). Participation in extracurricular activities and emotional and behavioral adjustment in middle childhood in Spanish boys and girls. *Journal of Community Psychology* 38(7), 842-857.

Paleti, R., Bhat, C.R., and Pendyala, R.M. (2013). Integrated model of residential location, work location, vehicle ownership, and commute tour characteristics. *Transportation Research Record* 2382, 162-172.

Paleti, R., Copperman, R.B., and Bhat, C.R. (2011). An empirical analysis of children's after school out-of-home activity-location engagement patterns and time allocation. *Transportation* 38(2), 273-303.

Panter, J.R., Jones, A.P., and van Sluijs, E.M.F. (2008). Environmental determinants of active travel in youth: A review and framework for future research. *International Journal of Behavioral Nutrition and Physical Activity* 5, 34.

Pew Research Center (2015). Children's extracurricular activities. *Parenting in America*. Ch. 5, pp. 65-73. Available at: http://www.pewsocialtrends.org/2015/12/17/5-childrens-extracurricular-activities/. Retrieved Jun 14, 2018.

Pinjari, A.R., and Bhat, C.R. (2010). Computationally efficient forecasting procedures for Kuhn-Tucker consumer demand model systems: Application to residential energy consumption analysis. Technical paper, Department of Civil and Environmental Engineering, University of South Florida.

Poitras, V.J., Gray, C.E., Borghese, M.M., Carson, V., Chaput, J.P., Janssen, I., and Sampson, M. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism* 41(6), S197-S239.

Pojani, D., and Boussauw, K. (2014). Keep the children walking: Active school travel in Tirana, Albania. *Journal of Transport Geography* 38, 55-65.

Price, C.D., Simpkins, S.D., and Menjívar, C. (2017). Sibling Behaviors and Mexican-Origin Adolescents' After-School Activities. *Journal of Adolescent Research* 32(2), 127-154.

Prinzie, P., Stams, G.J., Hoeve, M. (2008). Family processes and parent and child personality characteristics. In N.W. Slot, M. Hoeve (Eds.), *Tomorrow's Criminals: The Development of Child Delinquency and Effective Interventions* (pp. 91-102). New York: Ashgate.

Ramanathan, S., O'Brien, C., Faulkner, G. & Stone, M. (2014). Happiness in Motion: Emotions, Well-Being, and Active School Travel. *Journal of School Health* 84, 516-523.

Reisner, E. (2003). Understanding family travel demands as a critical component in work-family research, transportation and land use planning. In *Proceedings of the Academic Work and Family Research Conference*, Orlando FL.

Romero, V. (2015). Children's experiences: Enjoyment and fun as additional encouragement for walking to school. *Journal of Transport & Health* 2, 230-237.

Roth, M.A., Millett, C.J., and Mindell, J.S. (2012). The contribution of active travel (walking and cycling) in children to overall physical activity levels: A national cross sectional study. *Preventive Medicine* 54(2), 134-139.

Rothman, L., Macpherson, A.K., Ross, T., and Buliung, R.N. (2018). The decline in active school transportation (AST): A systematic review of the factors related to AST and changes in school transport over time in North America. *Preventive Medicine* 111, 314-322.

Safe Routes to School (2018). Safe Routes to School 101. *Safe Routes to School National Partnership*. Available at: https://www.saferoutespartnership.org/healthy-communities/101/about. Retrieved Mar 30 2018.

Sallis, J.F., Cerin, E., Conway, T.L., Adams, M.A., Frank, L.D., Pratt, M., … & Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: A cross-sectional study. *Lancet* 387, 2207-2217.

Saunders, L.E., Green, J.M., Petticrew, M.P., Steinbach, R., and Roberts, H. (2013). What are the health benefits of active travel? A systematic review of trials and cohort studies. *Plos ONE* 8(8), e69912.

Schoeppe, S., Duncan, M.J., Badland, H.M., Alley, S., Williams, S., Rebar, A.L., and Vandelanotte, C. (2015). Socio-demographic factors and neighbourhood social cohesion influence adults' willingness to grant children greater independent mobility: A cross-sectional study. *BMC Public Health* 15, 690

Schuepbach, M. (2015). Effects of extracurricular activities and their quality on primary school-age students' achievement in mathematics in Switzerland. *School Effectiveness and School Improvement* 26(2), 279-295.

Sener, I.N., and Bhat, C.R. (2007). An analysis of the social context of children's weekend discretionary activity participation. *Transportation* 34(6), 697-721.

Sener, I.N., Copperman, R.B., Pendyala, R.B. and Bhat, C.R. (2008). An analysis of children's leisure activity engagement: Examining the day of week, location, physical activity level, and fixity dimensions. *Transportation* 35(5), 673-696.

Sharmin, S., and Kamruzzaman, M. (2017). Association between the built environment and children's independent mobility: A meta-analytic review. *Journal of Transport Geography* 61, 104-117.

Simpkins, S.D., Delgado, M.Y., Price, C.D., Quach, A., and Starbuck, E. (2013). Socioeconomic status, ethnicity, culture, and immigration: examining the potential mechanisms underlying Mexican-origin adolescents' organized activity participation. *Developmental Psychology* 49(4), 706-721.

Simpkins, S.D., Vest, A.E., and Becnel, J.N. (2010). Participating in Sport and Music Activities in Adolescence: The Role of Activity Participation and Motivational Beliefs During Elementary School. *Journal of Youth and Adolescence* 39(11), 1368-1386.

Snellman, K., Silva, J.M., Frederick, C.B., and Putnam, R.D. (2015). The engagement gap: Social mobility and extracurricular participation among American youth. *The Annals of the American Academy of Political and Social Science* 657(1), 194-207.

Spissu, E., Pinjari, A.R., Bhat, C.R., Pendyala, R.M., and Axhausen, K.W. (2009). An analysis of weekly out-of-home discretionary activity participation and time-use behavior. *Transportation* 36(5), 483-510.

Stark, J., Beyer Bartana, I., Fritz, A., Unbehaun, W., and Hössinger, R. (2018a). The influence of external factors on children's travel mode: A comparison of school trips and non-school trips. *Journal of Transport Geography* 68, 55-66.

Stark, J., Frühwirth, J., and Aschauer, F. (2018b). Exploring independent and active mobility in primary school children in Vienna. *Journal of Transport Geography* 68, 31-41.

Stewart, T., Duncan, S., and Schipperijn, J. (2017). Adolescents who engage in active school transport are also more active in other contexts: A space-time investigation. *Health & Place* 43, 25-32.

Susilo, Y. O., and Waygood, E. O. D. (2012). A long term analysis of the mechanisms underlying children's activity-travel engagements in the Osaka metropolitan area. *Journal of Transport Geography* 20(1), 41-50.

Sweeting, H., and West, P. (2003). Young People's Leisure and Risk-Taking Behaviours: Changes in Gender Patterning in the West of Scotland during the 1990s. *Journal of Youth Studies* 6(4), 391-412.

Tackett, J.L., Slobodskaya, H.R., Mar, R.A., Deal, J., Halverson Jr., C.F., Baker, S.R., Pavlopoulos, V., Besevegis, E. (2012). The hierarchical structure of childhood personality in five countries: Continuity from early childhood to early adolescence. *Journal of Personality* 80(4), 847-879.

Tomasello, M. (2014). The ultra-social animal. *European Journal of Social Psychology* 44(3), 187-194.

Tranter, P., and Sharpe, S. (2012). Disney-Pixar to the rescue: Harnessing positive affect for enhancing children's active mobility. *Journal of Transport Geography* 20(1), 34-40.

Walking School Bus (2018). Walking School Bus. *National Center for Safe Routes to School*. Available at: http://www.walkingschoolbus.org/. Retrieved Mar 30 2018.

Waygood, E.O.D., Friman, M., Olsson, L.E., and Taniguchi, A. (2017). Children's incidental social interaction during travel international case studies from Canada, Japan, and Sweden. *Journal of Transport Geography* 63, 22-29.

Westman, J., Johansson, M., Olsson, L. E., Mårtensson, F., and Friman, M. (2013). Children's affective experience of every-day travel. *Journal of Transport Geography* 29, 95-102.

Wheeler, S., and Green, K. (2018). ‘The helping, the fixtures, the kits, the gear, the gum shields, the food, the snacks, the waiting, the rain, the car rides … ’: social class, parenting and children's organised activities. *Sport, Education and Society*, advance online publication.

Wong, S.C., and Ko, A. (2009). Exploratory study of understanding hotel employees’ perception on work–life balance issues. *International Journal of Hospitality Management* 28, 195–203.

Yang, X., Telama, R., Hirvensalo, M., Tammelin, T., Viikaric, J.S.A., and Raitakari, O.T. (2014). Active commuting from youth to adulthood and as a predictor of physical activity in early midlife: The Young Finns Study. *Preventive Medicine* 59, 5-11.

Yung, K.W.-H., and Bray, M. (2016). Shadow education: Features, expansion and implications. In T.K.-C. Tse, M.H. Lee (Eds.), *Making Sense of Education in Post-Handover Hong Kong: Achievements and Challenges* (pp. 95-111). Abingdon: Routledge.

Zhang, J., and Fujiwara, A. (2009). Intrahousehold interaction in transit-oriented residential choice behavior represented in stated preference approach. *Transportation Research Record* 2134, 73-81.

Zhang, R., Yao, E., and Liu, Z. (2017). School travel mode choice in Beijing, China. *Journal of Transport Geography* 62, 98-110.

Zwerts, E., Allaert, G., Janssens, D., Wets, G., and Witlox, F. (2010). How children view their travel behaviour: A case study from Flanders (Belgium). *Journal of Transport Geography* 18(6), 702-710.

Table 1. Sample descriptions (sample size = 552 children)

Variable	Category	Estimation sample		2016 Hong Kong Census Data[7]
		Freq.	%	
Age	5	9	1.6	
	6	54	9.8	
	7	99	17.9	
	8	99	17.9	
	9	108	19.6	
	10	87	15.8	
	11	70	12.7	
	12	26	4.7	
Gender	Male	315	57.1	51.6
	Female	237	42.9	48.4
Parent's educational attainment	Primary school and below	16	2.9	
	High school	242	43.8	
	Undergraduate or postgraduate studies	294	53.3	
Monthly household income (HK$)	< 30,000	223	40.4	48.9
	30,000 – 59,999	141	25.5	28.6
	>59,999	188	34.1	25.5
Number of motorized vehicles in household	0	387	70.1	84.9
	1	133	24.1	13.3
	2 or more	32	5.8	1.8
Number of children (siblings) in household	1	152	27.5	63.1
	2	332	60.2	33.0
	3 or more	68	12.3	3.9
Working status of parents	Both working	328	59.4	
	Both not working	12	2.2	
	Father works only	191	34.6	
	Mother works only	21	3.8	

[7] Obtained from Hong Kong's 2016 Population by-census (CSD, 2018), unless otherwise specified.

Table 2. Descriptive statistics of activity type participation and duration over the week days

Extra-curricular activity type	Total number (%) of individuals participating[8]	Mean duration of participation (mins)	Number of individuals (% of total number participating) who participate….[9]	
			Only in activity type	In the activity type and other activity types
Academic	269 (48.7)	197	62 (23%)	207 (77%)
Sports	281 (50.9)	140	84 (30%)	197 (70%)
Arts	246 (44.6)	97	49 (20%)	197 (80%)
Hobbies	102 (18.5)	134	12 (12%)	90 (88%)
In-home (outside good)	552 (100.0)	1530	55 (10%)	497 (90%)

[8] Percentages across rows in the column do not sum to 100% because some individuals participate in more than one activity type.

[9] Percentages sum to 100% for each row across the two columns, since the percentages are with respect to the total number of individuals participating in each activity type (the second column in the table).

Table 3. Estimation results of the joint model (t-stats in parenthesis)

Exogenous variable	Residential location density (RL choice utility; base RL alternative is low density)		Extra-curricular activity participation (ECAP baseline utility; base ECAP alternative is "in-home activity")				Active travel (ACT choice utility; base ACT alternative is "no active travel")	
	Medium density	High density	Academic	Sports	Arts	Hobbies	Some active travel	All travel is active travel
Alternative specific constant	-0.520 (-8.07)	-0.497 (-7.29)	0.432 (3.09)	0.497 (3.97)	0.296 (2.23)	0.232 (2.27)	-0.464 (-2.74)	0.190 (1.19)
Children characteristics								
Age	--	--	--	0.104 (2.72)	0.102 (2.15)	0.193 (4.12)	0.252 (1.99)	0.376 (3.14)
Gender (base is *Male*)								
Female	--	--	--	--	0.162 (5.79)	--	--	-0.146 (-2.52)
Household characteristics								
Parent's educational attainment (base is *high school and below*)								
Undergraduate or graduate studies	--	0.286 (5.58)	0.167 (4.72)	--	0.249 (2.01)	--	--	--
Household income (base is *>59,999 HK$*)								
<30,000 HK$	-0.131 (-3.03)	-0.158 (-2.33)	--	-0.271 (-2.12)	-0.172 (-4.54)	-0.271 (-2.12)	--	0.362 (2.74)
30,000 – 59,999 HK$	-0.079 (-2.11)	-0.101 (-2.19)	--	--	--	-0.202 (-3.31)	--	--
Presence of motorized vehicles in household	--	--	--	0.174 (4.39)	--	0.275 (3.27)	-0.264 (-2.21)	-0.452 (-3.41)
Presence of siblings	--	--	0.362 (5.31)	0.340 (2.84)	--	--	--	--
Both parents working	--	0.230 (4.28)	--	--	--	--	-0.391 (-3.78)	-0.127 (-2.05)
Residential location (RL choice; base is "low density")								
Medium density	na	na	--	0.147 (2.16)	0.100 (2.06)	--	0.178 (3.43)	0.135 (2.62)
High density	na	na	--	0.285 (1.99)	0.385 (3.46)	--	0.178 (3.43)	0.241 (3.33)
Active travel (ACT choice; base is "no active travel")								
Some active travel	--	--	--	0.111 (2.51)	--	--	na	na
All travel is active travel	--	--	--	0.269 (3.17)	--	--	na	na
Satiation parameters	na	na	2.090 (3.77)	2.211 (3.53)	1.641 (4.10)	1.985 (2.12)	na	na

--: Not significant, na: Not Applicable

Table 4. Estimated covariance matrix of errors in the joint model (t-stat)

Endogenous variable	Residential location density (RL choice utility; base RL alternative is low density)		Extra-curricular activity participation (ECAP baseline utility; base ECAP alternative is "in-home activity")				Active travel (ACT choice utility; base ACT alternative is "no active travel")	
	Medium density	High density	Academic	Sports	Arts	Hobbies	Some active travel	All travel is active travel
Residential location (RL choice; base is "low density")								
Medium density	1.00 (fixed)							
High density	0.50 (fixed)	1.00 (fixed)						
Extra-curricular activity participation (ECAP choice; base ECAP alternative is "in-home activity")								
Academic	0.00 (fixed)	0.00 (fixed)	1.00 (fixed)					
Sports	0.00 (fixed)	0.00 (fixed)	0.50 (fixed)	1.0 (fixed)				
Arts	0.12 (1.99)	0.27 (2.46)	0.50 (fixed)	0.5 (fixed)	1.0 (fixed)			
Hobbies	0.00 (fixed)	0.43 (1.98)	0.50 (fixed)	0.5 (fixed)	0.5 (fixed)	1.0 (fixed)		
Active travel (ACT choice; base is "no active travel")								
Some active travel	0.00 (fixed)	0.00 (fixed)	0.00 (fixed)	0.56 (2.15)	0.00 (fixed)	0.00 (fixed)	1.0 (fixed)	
All travel is active travel	0.00 (fixed)	0.20 (2.91)	0.00 (fixed)	0.41 (2.41)	0.00 (fixed)	0.00 (fixed)	0.5 (fixed)	1.0 (fixed)

(fixed): estimate is not statistically significantly different from the value it is fixed at.

Table 5. Aggregate measures of fit

Living in a neighbourhood of…	…and participating in extra-curricular activity corresponding to…	…and engaging in…	Actual percentage	Joint model prediction	Independent model prediction
Low density	Sports only	Active travel	5.62	4.65	4.12
Low density	Academic and Sports	Active travel	4.35	3.53	3.09
Low density	Academic, Sports and Arts	Active travel	3.80	3.34	2.82
High density	Academic only	No active travel	3.62	3.13	2.70
Low density	Academic and Arts	Active travel	3.44	2.80	2.38
Low density	Sports and Arts	Active travel	3.26	2.57	2.10
High density	Sports only	No active travel	3.08	2.33	1.97
Low density	Arts only	Active travel	3.08	2.67	2.49
Low density	Academic only	No active travel	2.90	2.44	2.20
Medium density	Academic and Sports	Active travel	2.54	1.82	1.56
Weighted mean absolute percentage error			na	18.06	29.12
Living in a neighbourhood of…	**…and time-budget spent in activity type corresponding to…**	**…and engaging in…**	**Actual percentage**	**Joint model prediction**	**Independent model prediction**
High density	Academic	No active travel	9.93	8.40	7.90
Low density	Academic	No active travel	8.77	7.95	7.62
Medium density	Academic	Active travel	8.26	7.14	6.82
Medium density	Sports	Active travel	5.77	4.35	3.63
Low density	Sports	Active travel	5.08	4.28	4.02
Low density	Hobbies	No active travel	4.75	4.15	3.84
Medium density	Arts	Active travel	3.14	2.63	2.50
Medium density	Hobbies	Active travel	2.97	2.33	2.10
High density	Sports	No active travel	2.97	2.44	2.08
Low density	Hobbies	Active travel	2.84	2.53	2.05
Weighted mean absolute percentage error			na	15.17	23.25

na: Not applicable

Table 6. Average treatment effects (ATE) corresponding to transplanting a random household from a lowest density neighbourhood to highest density neighbourhood (standard error in parenthesis)

Variable	ATE from joint model	ATE from independent model	% Difference Attributable to	
			"True" Effect	Residential Self-Selection Effect
Participation in				
Academic activities	-0.018 (0.002)	-0.022 (0.001)	82	18
Sport activities	0.114 (0.003)	0.127 (0.006)	90	10
Arts activities	0.155 (0.009)	0.189 (0.009)	84	16
Hobby activities	-0.012 (0.001)	-0.015 (0.002)	80	20
Active travel				
Some active travel	0.087 (0.005)	0.103 (0.004)	84	16
All active travel	0.106 (0.006)	0.122 (0.002)	87	13

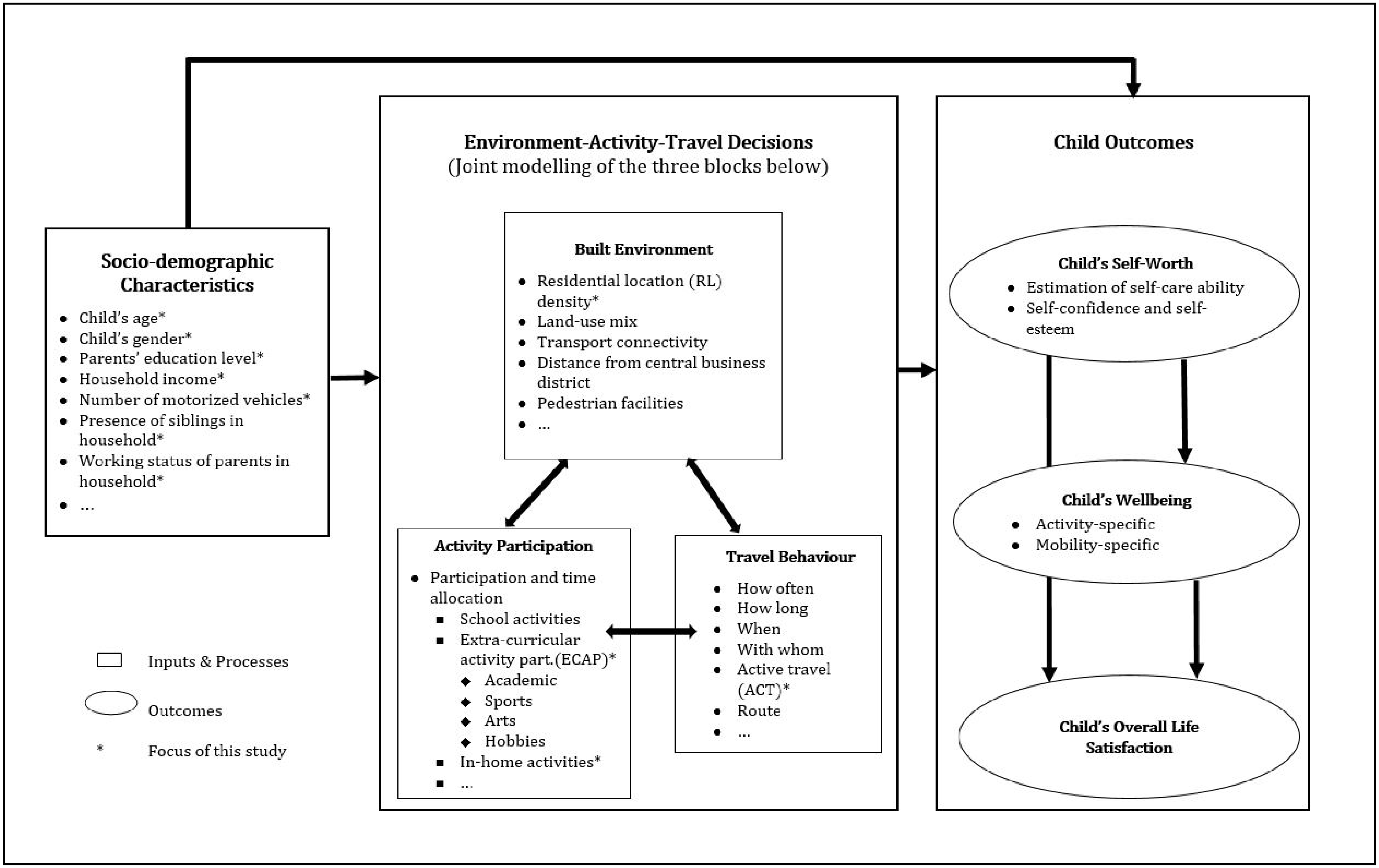

Figure 1. The Environment-People Interactions Framework