

The deeper and wider social impacts of transportation infrastructure: From travel experience to sense of place and academic performance

Ho-Yin Chan¹, Zhuowei Wang², Yingying Xu², and Anthony Chen^{2,*}

¹ School of Geography and the Environment, University of Oxford

² Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong

*Corresponding author: anthony.chen@polyu.edu.hk

Abstract

Traditional transportation planning emphasized the direct economic benefits of transportation infrastructure. While there is a growing awareness of the environmental consequences, social impacts are frequently overlooked due to methodological complexities and political neglect. Although existing literature acknowledges the existence of transportation-related social exclusion, it primarily concentrates on quantifiable and immediate short-term social outcomes arising from improved accessibility and affordability, which facilitate place-to-place interactions and activities. There has been limited exploration of the more intricate and indirect societal impacts associated with transportation. This paper argues that new transportation infrastructure not only affects mobility and travel experiences but also has deeper social impacts on the sense of place. These effects may extend to broader benefits, including academic performance, by influencing place identity, attachment, and dependency, which in turn affect daily activities unrelated to travel. Our study focuses on a university student community ($N = 323$), a pivotal future workforce, and investigates how the introduction of a new metro line passing through the campus reduces commuting time, subsequently enhancing academic productivity. Employing structural equation modeling method, our analysis reveals that sense of place acts as a mediator between travel experience and student engagement under the influence of transportation mode choice. These findings may have broad applicability in identifying indirect social impacts of transportation infrastructure, thus providing insights for investment decisions.

Keywords: Wider social impact; Transportation infrastructure; Sense of place; Academic productivity; Student engagement; Hong Kong

Highlights

- Place-centered approach for assessing social impact of transport infrastructure
- Focus on a student community as non-working population but future workforce
- Investigate deeper/wider impact to/from sense of place on academic productivity
- Case study of a recent metro extension project, Shatin to Central Link, in Hong Kong
- Switching from bus to train enhances SoP and academic performance.

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1. Introduction

Transportation infrastructure projects play a pivotal role in fostering economic growth and enhancing societal well-being by facilitating the connection of individuals, commodities, and services (Chan et al., 2023; Jiang et al., 2017; Qi et al., 2020; Song and van Geenhuizen, 2014; Yu et al., 2013). Beyond expediting the movement of people and goods, the development of transportation infrastructure yields a diverse array of impacts that transcend the confines of the transportation sector. The initial assessment typically involves first-order user effects, as determined by Cost-benefit analysis (CBA) (Li and Loo, 2016). While CBA stands as a prevalent evaluation method in many industrialized nations, it is noteworthy that, in most instances, it constitutes just one component within a broader framework of evaluation. Regrettably, within this evaluation process, social impacts often receive less emphasis compared to economic and environmental impacts (Jones and Lucas, 2012; Lucas et al., 2022; Mottee et al., 2020). This marginalization of social assessments can be attributed, in part, to the limited political emphasis, resulting in a reluctance to allocate substantial resources to these assessments during the commissioning phase (Lucas et al., 2022).

In order to successfully navigate the intricate landscape of social impact assessments, it is imperative for project teams, often helmed by individuals with backgrounds in engineering, project management, and decision-making, to possess a nuanced understanding rooted in the social sciences foundational to social impact assessments (Arce-Gomez et al., 2015; Mottee and Howitt, 2018; Ross and McGee, 2006). These professionals serve as the backbone for integrating comprehensive insights into the social fabric, ensuring that assessments go beyond mere quantitative metrics to embrace the qualitative nuances essential for a holistic evaluation. The call to explore the possibilities of crossing the boundary and forging creative connections between critical-qualitative and analytical-quantitative social assessments (Lucas et al., 2022) and transportation geography (Kwan and Schwanen, 2009) underscores the evolving nature of research methodologies within the field. The expertise cultivated by the diverse practitioner teams, equipped with a multidisciplinary foundation, becomes instrumental in navigating this boundary-crossing endeavor (Harvey and Bice, 2014; Howitt, 2005). By amalgamating critical-qualitative rethinking with analytical-quantitative methodologies, these project teams can enhance the depth and breadth of their social impact assessments, yielding more comprehensive and nuanced insights into the intricate interplay between infrastructure projects and the communities they impact.

This study begins with the premise that social impacts are intricately linked to specific geographic and societal contexts, leading to diverse experiences across regions and individuals (Schwanen, 2018, 2017). Social assessments play a crucial role in preventing a diminished quality of life and social exclusion as unintended consequences of transportation project investments. The article highlights the effectiveness of adopting a place-centered approach, emphasizing specific geographic and societal contexts to enhance this process. The concept of “*place*” encompasses both the physical and human characteristics of a location (Cresswell, 2009). Unlike location, which implies a higher degree of certainty and precision, place is more subjective and may exhibit a higher degree of vagueness. It is a highly personal, experiential concept influenced by individual perceptions and emotions. The term “*sense of place*” refers to the subjective and emotional connection that individuals or communities develop with a particular location (Cresswell, 2004; Massey, 2008, 2004; Urry, 2007). Contrary to the traditional approach that associates sense of place with fixity, boundedness, and rootedness, the recent mobility turn, as recognized by scholars like Cresswell (2002) and Massey (2008), acknowledges the importance of mobility. This shift emphasizes the subjective experience of place and underscores the role of mobility in shaping our the understanding and sense of place (Cresswell, 2023). This study demonstrates how new transportation infrastructure impacts mobility/travel experiences and delves into the deeper social implications on the sense of place, considering how these factors might translate into wider benefits including academic performance.

This study aims to underscore the significance of evaluating social impacts when assessing the wider benefits of new transportation infrastructure. We investigate the impact on the sense of place—one of the aspects in defining and evaluating social impacts on a place and its communities—to exemplify how the deeper effects can extend to wider impacts. We conduct a case study on a distinct community: university students, representing a non-working population that significantly shapes the region’s future workforce. The investigation delves into how the introduction of new metro lines passing through the campus can reduce commuting times and, consequently, enhance academic productivity:

1. Our approach delves into the deeper social impacts of transportation infrastructure and its broader consequences on non-working communities. It

goes beyond merely examining an individual's subjective conditions; it also considers wider impacts, such as students' academia performance.

2. By exploring the implications of a "sense of place" from a mobility perspective and its relationship with travel experiences and behaviors, we can broaden our understanding of "place" within the field of transportation.

In the upcoming sections, we will first explore the impact mechanism of transportation infrastructure on the sense of place, which leads to deeper social implications. Following that, we will conduct a case study to evaluate how the sense of place contributes to wider social impacts on student engagement and productivity, completed with methods for measurement and estimation. Subsequently, we will present our modeling results, which highlight the role of the sense of place as a mediator in the relationship between commuting time, travel experiences, and key factors such as student engagement, enrollment, and productivity. To conclude, we will discuss the policy implications drawn from our findings.

2. Literature review

2.1 The deeper social impact on the sense of place

Social impacts include the practical effects of significant transportation investments on people's lives, encompassing both positive outcomes (social benefits) and negative consequences (human burdens) (Lucas et al., 2022). From a systemic perspective, development of transportation infrastructure involves not only the spatial expansion for broader service, but also deeper impacts entailing instigating change at cultural and personal levels, affecting inter- and intra-community relationships (Fraser and Glass, 2020). This work is inherently relational, involving the transformation of mindsets, perceptions, cultural practices, habits, and values. However, due to the often localized, culturally specific, historically rooted, and socially embedded nature of these impacts, as well as the complexity of establishing causal relationships associated with deeper social consequences, the assessment of such impacts is conventionally challenging. Consequently, they are often overlooked in the context of the "planning for all" paradigm, which leads to a reluctance to allocate substantial resources during the commissioning phase (Lucas et al., 2022).

For the deeper effects, the "sense of place" holds a significant role within both personal identity on a deep level and cultural identity on a broader scale of

community. In Cresswell (2004)'s well-regarded book *Place: An Introduction*, sense of place is defined as *"the subjective and emotional attachment people have to a place"* (p. 14). To truly understand this concept, it necessitates delving into people's emotions and perceptions. This is especially crucial when considering the construction of new transportation infrastructure, which can be seen as a two-stage process. The first stage involves detaching individuals from their previous associations with specific travel routes (direct impact), followed by the possibility of physically relocating homes and workplaces (wider impact) (Rayle, 2015). The subjective nature of sense of place transcends physical attributes and encompasses intangible elements that give a place its uniqueness. Emotional attachment to a place involves deep emotional connections and a sense of belonging that individuals or communities form with a particular location. This attachment can be positive or negative and is shaped by experiences, relationships, and the significance ascribed to that place. As Massey (1994)'s pioneer paper points out, place is not only about the physical transformation of the built environment but also about the evolution of social perceptions through urban (re)development and how these changes contribute to capital accumulation. From a mobility perspective, one's sense of place is influenced by the intricate and ever-evolving networks created by changes in the built environment, such as the introduction of new transportation infrastructure (Jackson and Buckman, 2020), as well as daily interactions with urban amenities and recurrent travel experiences at various locations (Westerholt et al., 2022). Transportation itself can be seen as a means of connecting different places and communities (Audirac, 1999; Jackson and Buckman, 2020). This concept is particularly applicable in transit-oriented development (TOD), which aims to establish communities where people can live, work, and engage in recreational activities within walking distance of public transportation hubs, like train or bus stations (Dorsey and Mulder, 2013; Hess and Lombardi, 2004). Taking a closer look at Hong Kong, the study by Xue et al. (2012) reveals how metro stations, strategically located at centers of daily necessities (e.g., travel, residence, dining), with multiple accessible connections to nearby developments and encircled by roadways and railway lines, foster a sense of centrality and enclosure. This continuous interplay between indoor and outdoor environments fosters a strong sense of place and community. From a regional perspective, the understanding of a place's perceived meanings evolves over time in tandem with the city's economic development and its associated surroundings (Saeed and Furlan, 2019; Rykwert, 2002). It has been observed that the perceived quality, as indicated by sense of place, is lower in developing areas, even though these areas rank highly in

terms of spatial and economic development compared to national railway stations (Du et al., 2021).

Aligned with the concept of identity construction processes, the notion of “*sense of place*” portrays place as a pivotal element in subjectivity. This concept holds significant analytical power as it transforms the abstract notion of “*space*” into a concrete “*place*” through the actions and experiences of individuals (Massey, 1994; Mendoza and Morén-Alegret, 2013; Relph, 1976; Tuan, 1979). Space and place are ‘dialectically structured in human environmental experience’ (Relph, 1976; Seamon and Sowers, 2008, p.44). The sense of place, cultivated through everyday experiences and subjective emotions, can be so profound that it becomes a central component in shaping an individual’s identity (Massey, 1996). Place has long been a locus of meaning linked to a rooted and authentic sense of identity. It serves as a subset of one’s overall identity and pertains to the role a place plays in molding an individual’s self-concept. People often derive a portion of their identity from the places they inhabit or have a connection with, encompassing cultural, social, and emotional bonds to specific locations. In the realm of transportation literature, identity has been found to intersect with travel behaviors. An individual’s self-concept, identity, and self-esteem are closely intertwined with their daily choices of travel modes (Ingvardson et al., 2021; Murtagh et al., 2012; Senikidou et al., 2022), with a particular emphasis on the decision between public and private transportation modes. For example, low-income young individuals tend to prefer public transportation over private cars, while high-income professionals are more likely to own cars, earn higher incomes, and use cars more frequently. Furthermore, this identity has also been associated with a resistance to change in transportation mode (Heinen, 2016). Beyond personal identity, the literature also suggests that various transportation modes can represent different ways of perceiving and embodying a sense of place (Aldred and Jungnickel, 2012; Wunderlich, 2008). Car usage is characterized by lower place dependence and satisfaction but a higher sense of place identity when compared to pedestrians, who often connect with their subjective travel experiences, emotions, and feelings (Deutsch et al., 2013). In contrast, the use of public and active transportation modes is positively linked to a sense of place, with travel satisfaction and experience serving as mediating factors (Chan et al., 2024; Di Masso et al., 2019; Dixon et al., 2022; Liu et al., 2023). Travel satisfaction and experience are influenced by various physical factors, such as travel time (Nguyen-Phuoc et al., 2018), number of transfer (Anderson et al., 2017), walking (Boulangé et al., 2017; De Vos et al., 2022b) and waiting (Lunke, 2020) time, seat availability (Wardman and Whelan, 2011),

interactions with people along the travel route (Chan, 2024; Zahnow and Corcoran, 2024) and psychological factors such as travel time uncertainty (Chen et al., 2011). It is also suggested that public transportation users typically move more rapidly, pay less attention to their surroundings, and interact with the built environment less frequently, resulting in a weaker sense of place compared to pedestrians and cyclists (Wunderlich, 2008). This observation can also be extended to people traveling with companions, who generally exhibit a lower sense of place, likely due to their interactions with people rather than places (Deutsch et al., 2013).

The existing literature highlights concerns regarding the interplay between a person's sense of place, especially their place identity, subjective attachment, travel experiences, and choices of transportation modes. Consequently, this prompts us to formulate our first argument:

A1. (a) Transportation mode has significant effects on travel experiences, and (b) both would affect the sense of place.

2.2 The wider social impact on student engagement and productivity

Despite the prevailing dominance of Cost-Benefit Analysis (CBA), there have been persistent efforts to evaluate a wider spectrum of impacts associated with transportation projects (Feldman et al., 2008; Lakshmanan, 2011; Legaspi et al., 2015). These impacts are often collectively referred to as social and economic impacts, project externalities, or, more recently, the “*wider social and economic impacts*” of transportation projects. Examples encompass a wide range, such as environmental effects like pollution or noise (Tsoi et al., 2023), benefits to the natural habitat (Mancebo Quintana et al., 2010), visual intrusion, health impacts (Cavill et al., 2008), accessibility (Mann and Levinson, 2024; Tsamboulas et al., 2013; Xu et al., 2024, 2022), land use planning, agglomeration, labor displacement, habitat fragmentation, and equity considerations. The specific set of wider impacts that should be considered in practice is not formally agreed upon and is likely to vary depending on the nature of the project in question. The decision on whether to incorporate wider impacts in a transportation appraisal often corresponds with the widespread expectation that transportation infrastructure projects will generate wider economic benefits (Laird and Mackie, 2014; Roberts et al., 2020; Rosik and Wójcik,

2022; Rothengatter, 2017; Wang et al., 2019; Xuto et al., 2023; Zhou et al., 2022). Quantitative assessment framework is always based on the premise that changes in transportation costs should be reflected in changes in accessibility, which in turn alter the demand for land, ultimately affecting the level and pattern of prices and outputs. It is evident that transportation infrastructure, accessibility, and land use planning are interconnected and ideally should be assessed within a unified framework. It is worth mentioning that transportation can also create a barrier effect, influencing certain land-use decisions where specific unfavorable transportation conditions are avoided. For example, urban redevelopment may tend to occur away from a transportation crossing or result in reduced economic activities in the vicinity of such crossings (Gbban et al., 2023).

Among different social groups, there is often a tendency to focus on the quantifiable social benefits, such as improved accessibility for the working population, which directly contributes to economic value through time savings. Unfortunately, one frequently overlooked aspect is the potential economic contribution of the non-working population, including the student community we are examining in this study. The social impact of improved accessibility to education has been extensively documented in the literature (Guzman et al., 2017; Lois et al., 2018; Ross et al., 2020; Tiznado-Aitken et al., 2021). Enhanced urban public transport, for example, has been shown to influence student enrollment levels, a factor with significant implications for social progress (Kenyon, 2011). This accessibility improvement could also exacerbate educational inequalities, especially if educational policies lead to the spatial concentration of public schools, known as school agglomeration (Moreno-Monroy et al., 2018).

In the realm of higher education research, there is a substantial body of work examining various factors that influence university students' academic performance. These factors include aspects like learning motivation and student engagement. Within this body of research, some studies have delved into the significance of undergraduates' sense of place in shaping their academic outcomes (Temple, 2009). It is important to recognize that the physical environments within higher education institutions not only facilitate the learning process but also convey specific values and aspirations associated with different fields of study in higher education (Sturner, 1972). Higher education institutions carefully design their campus environments to nurture students' sense of place and promote academic success (Holton, 2015; Kuntz et al., 2012). A limited number of studies have explored the correlation between

student engagement and their sense of place (Okoli, 2013) or the relationship between their sense of place and academic achievement (Getz and Lev-Ari, 2017). Student engagement is a multidimensional concept encompassing cognitive efforts, interactions with instructors, and active participation in class (Hsieh, 2022, 2014). Previous research has demonstrated that student engagement serves as a mediating factor in the connection between students' perceptions of the learning environment and their academic achievement (Guo et al., 2022; Guo, 2018; Lizzio et al., 2002; Schaeper, 2020). Furthermore, higher academic productivity, as indicated by GPA at graduation, has been associated with higher salary levels, suggesting its potential for economic contributions when students enter the workforce (Tebaldi et al., 2017; Zou et al., 2022). Therefore, we put forth our second argument as follows:

A2. (a) Sense of place has positive effects on student engagement, and then (b) affect their academic productivity

2.3 The measurement scale

To quantify a person's sense of place, we adopt a measurement model from Jorgensen and Stedman (2001). Selecting Jorgensen's sense of place measurement model was motivated by its comprehensive framework, capturing various dimensions of sense of place such as place attachment, identity, and dependence. This model has been widely recognized for its validity and reliability in assessing the nuanced aspects of individuals' connections to a specific location in transportation studies (Chen and Sekar, 2018; Deutsch et al., 2013; McCunn and Gifford, 2018; Sekar et al., 2017). Questions and statements are summarized in **Table 1**. This model comprises of three essential components – place identity, place attachment, and place dependence – and each reflects a different facet of an individual's relationship with a place. Place identity represents an individual's cognitive and emotional attachment to a specific place. It encompasses the sense of recognition and deep emotional connection where the person feels that the place holds significant meaning within their identity. Place attachment, on the other hand, refers to the emotional bond that forms between an individual and a place. This emotional connection includes feelings of affection, care, and a profound attachment to a particular environment or location. Lastly, place dependence addresses the practical and behavioral dimension of an individual's connection to a place. It revolves around the reliance on a specific location for various activities and needs, underscoring the importance of that place in an individual's daily life. These three dimensions provide a comprehensive framework for understanding

how individuals perceive and interact with their surroundings. Subsequent studies (e.g., McCunn and Gifford, 2018; Westerholt et al., 2022) have utilized these dimensions to assess and measure the sense of place in various contexts, shedding light on the intricate connections people have with their environments.

For student engagement, we adopted the scale from Hsieh (2022) consisting of three aspects. Active participation is defined as behaviors such as asking questions in class, contributing to class discussions, presenting class presentations, or working with other students on projects during class; Interactions with instructors referred to behaviors such as discussing with instructors and learning experiences. Cognitive effort is defined as how much time students spent on the courses.

After thoroughly reviewing the literature, we ask: do transportation projects exert a profound impact on an individual’s inherent sense of place, as well as to extend their influence on broader social dimensions? To systematically examine these relationships, we have formulated a conceptual model encompassing the following key hypotheses for empirical testing (**Figure 1**). We first explore the impact of travel experiences on the sense of place and how transportation modes influence these experiences. Subsequently, we delve into whether the sense of place has effects on student engagement, thereby influencing their academic productivity. Finally, we assess the academic productivity resulting from the social impacts of a new metro line running through the campus.

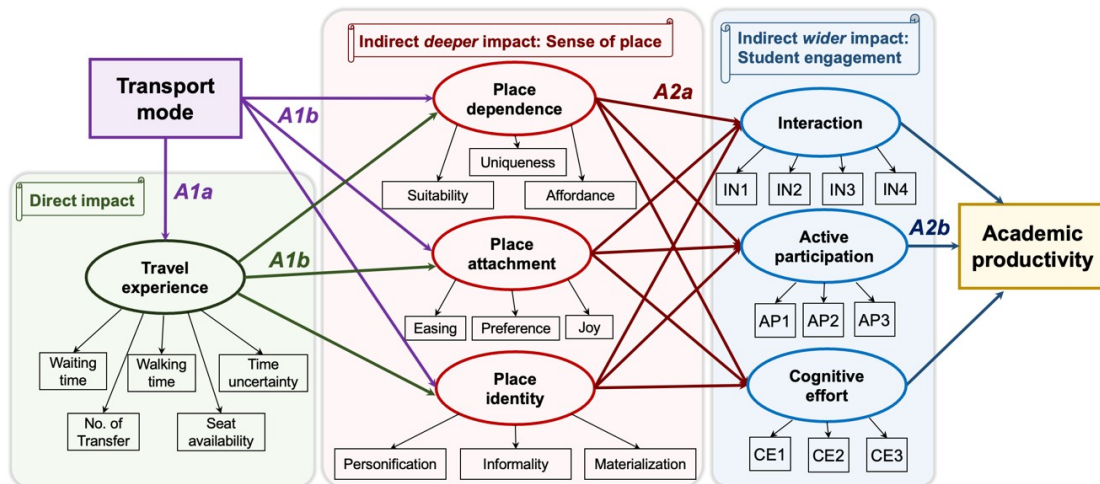


Figure 1 Conceptual model

3. Data and Methodology

3.1 Case study

The metro system, Mass Transit Railway (MTR), is the dominant public transportation mode in Hong Kong, with over 47% of the market share in the public transportation market (Transportation Department, 2014a). 271 km route length and 99 metro stations cover nearly all the urban areas in Hong Kong, and it continues to be expanded in stages.

In Hong Kong, most urban university campuses are located near metro stations (Chan et al., 2021). We focus on a university student community at the Hong Kong Polytechnic University (PolyU), of which campus located at the Hung Hom metro station, where the new extension of the SCL passes through. The study area is depicted in **Figure 2** and it comprises the connection and extension of the Tai Wai to Hung Hom section, which opened in June 2021, and the Hung Hom to Admiralty section, which opened in May 2022. Hung Hom station is an existing station, and the opening of the SCL directly connects the Northeast New Territories and Hong Kong Island to Hung Hom. Also, it became the fourth cross-harbour railway line to connect Hung Hom to Hong Kong Island. The extension of the railway system diversifies the mode and route choice options for people who commute to/from the PolyU campus. Besides, the university campus is a densely populated school/workplace and, thus, a transportation activity generator. Any university must deal with the transportation issue as students, staff, and visitors commute to and from campus, representing one of the university's most critical impacts on the local transportation system.

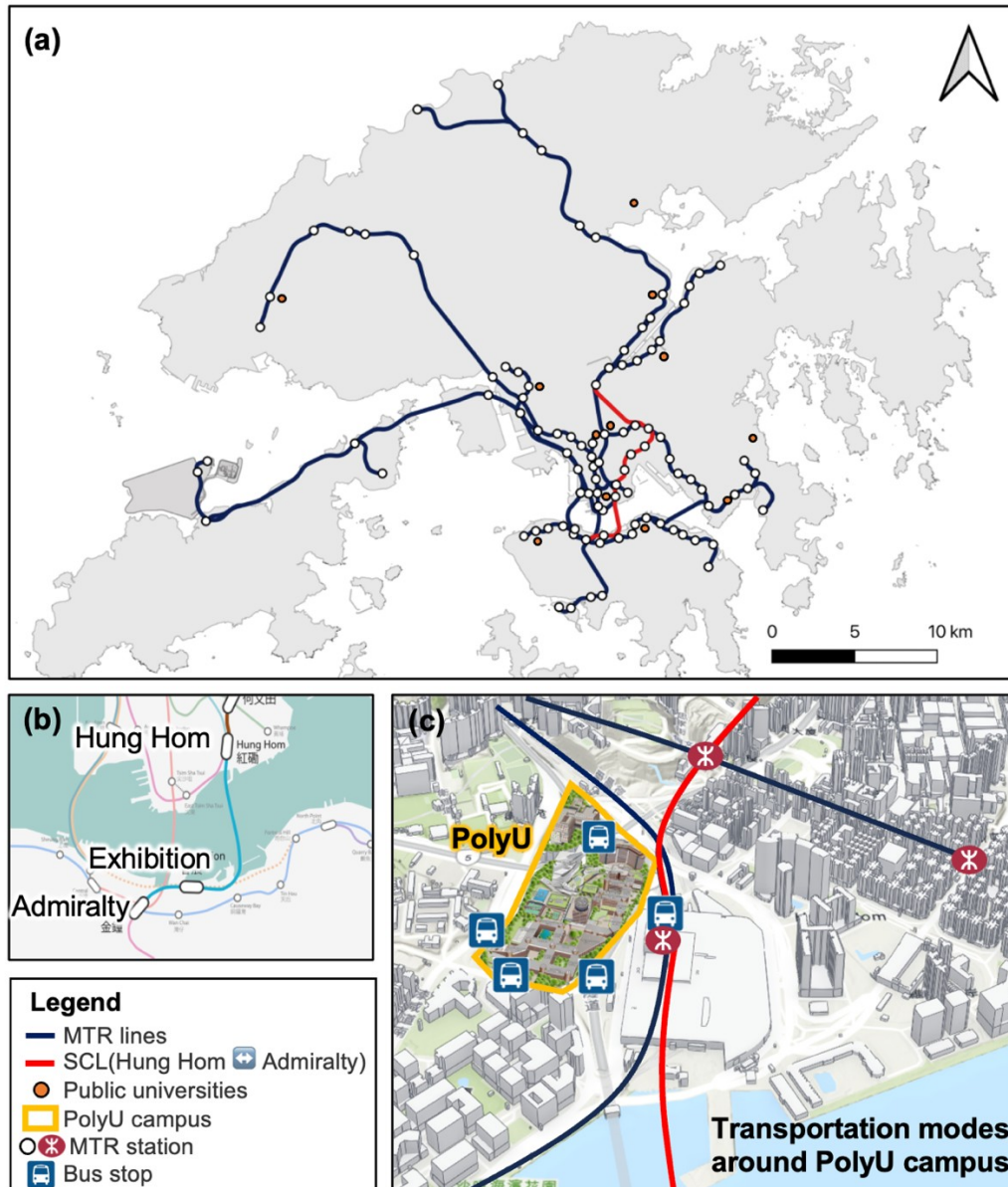


Figure 2 Transportation mode choices available for accessing PolyU Campus (a) HK's MTR system, (b) SCL from Hung Hom to Admiralty, and (c) transportation modes around PolyU campus

3.2 Data collection and analysis

3.2.1 Questionnaire design

The designed questionnaire comprises five main sections of questions, which includes the transportation related questions including modal choice before/after the opening of SCL, travel preference, travel experience, and the sense of place, academic engagement and achievement and demographics. Other information includes personal characteristic, transportation mode choice, travel experience, travel preference, student engagement and productivity as shown in **Table 1**.

3.2.2 Survey administration

The face-to-face survey was administered by trained university students. Respondents were randomly selected around the entrance of PolyU campus. A preliminary pilot study involving 10 participants was carried out to gather feedback from students prior to the main survey. Notably, respondents predominantly commented on the questionnaire's length. In response to this feedback, we ensured that only variables with theoretical support were included. This determination was made by referencing the relevant column in the table. Main survey was conducted from January 2023 to February 2023, and 323 responses were collected. Details of social and demographic characteristics are summarized in **Table 1**. The sample is broadly representative, with a male-to-female ratio of 0.7:1, deviating slightly from the official statistic¹ of 0.9:1. The duration of stay at PolyU is typically distributed across 1 to 4 years, aligning with the standard duration of the university's undergraduate degree programs. To determine the distances to the campus, we calculated from the geographical coordinates (latitude and longitude) of both the participants' residential districts and the university campus. The walking/waiting times were set at 10 minutes as the threshold, consistent with the acceptable time threshold established in the most recent household survey on travel characteristics in Hong Kong (Transportation Department, 2014b).

Table 1 Social and demographic characteristics of the sample

Variable	Reference	Statement/question	Code	Mean (SD)/ %	
	Pourhashem et al. (2022); Prieto et al. (2017)	Gender	Male or female	Male = 1; Female = 0	1: 41%; 0: 59%
	Feng et al. (2014);	Familiarity	Years stayed	at 1 year or below = 1; 2 = 2; 3 = 3	1: 37%; 2: 30%;

¹ <https://www.polyu.edu.hk/en/ipao/facts-and-figures/>

	Harms et al. (2021)	PolyU	4 = 4 ; 5-10 = 5 ; Above 10 years = 3: 20%; 4: 11%; 6 5: 2%; 6: 0%
<i>Promixity to campus</i>		Location of Distance (km) calculated from the residence at district lat and lng of the locations of level residence and university campus	6.61 (6.56)
<i>Promixity to metro station(s)</i>		Walking time between location of 1: More than 10 Minutes; 0: Less residence and the than 10 Minutes nearest metro station	1: 42%; 0: 58%

3.3 Extraction of variables

perform an exploratory factor analysis (EFA), employing an iterative process that involved eliminating indicators with cross-loadings and evaluating fit indices (see **Table 5**). Ultimately, we arrived at a final factor structure.

Regarding travel experiences (**Table 2**), our focus lies in understanding the impact of the introduction of a new metro line on individuals' mode choice and travel experiences. To delve into this, we inquired about variables related to experiences that were identified in the literature review. We approach travel experiences as multifaceted, utilizing latent variables (e.g., Kim and Chen, 2019; Mustelier Puig and Ming, 2017) to encapsulate the collective influence of elements such as comfort, ambiance, and service quality (Golob, 2003). Latent variables offer a means to model complex, underlying constructs that may not be directly measurable. This methodology becomes particularly beneficial in situations where a set of variables may lack significant correlations with a dependent variable when examined individually. In the questionnaire, we asked them to rate statements related to travel utility on a five-point scale, ranging from 'strongly disagree' (1) to 'strongly agree' (5). An EFA revealed that the uncertainty functioned as a standalone observed variable, while walking and waiting time and seat availability loaded onto the same factor, with a Cronbach's alpha of 0.60.

Table 2 Trip characteristic of the sample

Variable	Reference	Statement/question	Code	Mean (SD)/ %	
				Before [#]	After [#]

Mode shift	Since the Shatin-Central Link opened, have you changed your preferred commuting mode to and from the campus?	1: Yes ; 0: No	1: 37%; 0: 63%
Mode choice (before/after)	Transportation modes to/from campus	1: bus; 2: metro; 3: others including private modes and walking	Fig. 3
Travel experience (before/after)	Nguyen-Phuoc et al. (2018)	Travel time to campus	Continuous variable (mins) 30.92 (15.98) 32.20 (15.69)
Transfer	Anderson et al. (2017)	What is the number of transfers required?	0: 0%; 1: 22%; 2: 22%; 3 or above: 32% 0: 60%; 1: 31%; 2: 9%; 3: .01%
Walking Time	Boulangue et al. (2017); De Vos et al. (2022b)	What is your total walking time required for your trip from home to campus?	1: More than 10 Minutes; 0: Less than 10 Minutes 1: 46%; 0: 54%
Waiting Time	Lunke (2020)	What is your average waiting time required for your trip from home to campus?	1: More than 10 Minutes; 0: Less than 10 Minutes 1: 19%; 0: 81%
Uncertainty	Chen et al. (2011)	What is your additional budget time?	1: More than 10 Minutes; 0: Less than 10 Minutes 1: 33%; 0: 67%
Seat unavailability	Wardman and Whelan (2011)	During travelling, you most often sitting/standing?	1: Standing; 0: Sitting 1: 51%; 0: 49% 1: 51%; 0: 49%

Before and after the construction of the new metro line, if applicable.

For student engagement (**Table 3**), we adopted the scale from Hsieh (2022) consisting of three aspects: active participation, interactions with instructors, and cognitive effort. The responses exhibit a dispersed distribution, avoiding concentration around the “neutral” point. This dispersion enables a thorough assessment of the variability in responses. The internal consistency and construct reliability of the structure for active participation, interaction, and cognitive effort found to be acceptable with Cronbach’s alpha values > 0.5.

Table 3 Scale and statistical results for the student engagement

Variable	Reference	Statement/question	Code	Mean (SD)/ %
Active Participation	Hsieh (2022)	AP1: I used to arrive to classes on time.		3.24 (1.03)
		AP2: I used to take notes in the class.		3.30 (1.01)
		AP3: I used to ask questions in class or contributed to class discussions		3.32 (0.93)
Interactions		IN1: I used to discuss class assignment with instructors.	Five-point Likert	3.14 (0.90)
		IN2: I used to discuss the materials I do not understand with instructors.	scale: disagree = 1, strongly disagree = 2, neutral = 3, somewhat agree = 4, and strongly agree = 5	2.85 (1.00)
		IN3: I used to discuss ideas from my readings or classes with instructors.		2.50 (0.97)
		IN4: I used to talk about my learning plans with the instructors.		2.86 (1.04)
Cognitive Effort		CE1: I used to preview class materials before the class.		3.22 (0.99)
		CE2: I used to review class materials after the class.		3.31 (1.05)
		CE3: I used to make a plan to review class materials before exam.		3.22 (1.01)
Academic productivity	Getz and Lev-Ari (2017)	What is your Cumulative Grade Point Average (CGPA) for your major?	<=1.69 = 1, 1.70–2.39 = 2; 2.40–2.99 =3; 3.00–3.59 = 4, 3.60–4.30 = 5	1: 4%; 2: 3%; 3: 29%; 4: 54%; 5: 10%

We assessed the sense of place (**Table 4**) using the dimensions of attachment, dependence, and identity, as employed by Jorgensen and Stedman (2001). Our goal was to replicate a successful method for quantifying the sense of place. However, we encountered challenges as our data did not fully conform to the predefined structure. We first tested with the original structure to investigate whether the standardized path coefficients > 0.7 and with Cronbach's alpha values > 0.5 (Mokarami et al., 2019). We find the standardized path coefficients of all items except suitability from the place dependency category < 0.7 and Cronbach's alpha values of place identity, attachment and suitability are 0.63, 0.56, and 0.31, which is not ideal. We therefore treat them as single reported value as they all present a specific meaning of easing, joy, preference, personification, informality, materialization, suitability, uniqueness, and affordance.

Table 4 Scale and statistical results for the sense of place

Variable	Reference	Statement/question	Code	Mean (SD)/ %
Place attachment	Jorgensen and Stedman (2001); McCunn and Gifford (2018); Westerholt et al. (2022)	I feel relaxed when I'm in this scale: area. I feel happiest when I'm in this area. This area is my favorite place to be.	Five-point Likert disagree = 1, somewhat disagree = 2, neutral = 3, somewhat agree = 4, and strongly agree = 5	3.13 (1.08) 3.42 (1.23) 3.11 (1.16)
<i>Easing</i>				
<i>Joy</i>				
<i>Preference</i>				
Place identity		Everything about this area is a reflection of me.		3.02 (1.12)
<i>Personification</i>		I feel that I can really be myself in this area.		3.35 (1.27)
<i>Informality</i>		This area reflects the type of person I am.		3.29 (1.33)
<i>Materialization</i>				
Place dependence		This area is the best place for doing the things that I enjoy most.		3.18 (1.23)
<i>Suitability</i>		For doing the things I enjoy most, no other place can		3.33 (1.19)
<i>Uniqueness</i>				

<i>Affordance</i>	compare to this area. This area is a good place to do the things I like to do most.	2.81 (0.94)
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Table 5 Factor loading of sense of place and travel experience variables.

Student engagement				Travel experience		
Dimension	Factor loading			Dimension	Factor loading	
	Active participation	Interaction	Cognitive Effort		Travel experience	Uncertainty
AP1	.5022	.0325	-.0003	Transfer	.3018	.2610
AP2	.5773	-.0686	-.0394	Walk	.4959	.1304
AP3	.5533	.0400	.3584	Wait	.3586	.3262
IN1	.3165	.3072	.0356	Uncertainty	.0000	1.0413
IN2	.4070	.5883	-.1771	Seat	.5323	.1317
IN3	.1745	.3721	-.0025			
IN4	.0820	.5181	.3794			
CE1	-.1335	-.0925	.5758			
CE2	-.2483	-.2258	.7181			
CE3	.0780	-.2757	.6067			
Cronbach's alpha	.5739	.5295	.7009		.6019	-

3.4 Structural equation modelling

We employed structural equation modeling (SEM) as our primary analytical tool, utilizing Stata SE/17.0 for the analysis. SEM is a powerful statistical technique that enables the modeling of complex relationships among various variables, both endogenous (those influenced by other variables) and exogenous (those that influence other variables) (Anderson and Gerbing, 1988; Golob, 2003). A complete SEM model consists of a measurement model, which defines the relationships between latent variables (unobserved constructs) and their corresponding observed variables, and a structural model that specifies the assumed relationships among these latent variables, as well as the interrelationships among the endogenous variables themselves (Deutsch

et al., 2013; Tao et al., 2019). Given that our study deals with latent variables like “*student engagement*” and “*travel experience*” captured through multiple measurements, as well as numerous interconnected dependencies, such as socio-demographic factors, SEM is an ideal choice for our research objectives. The structural model can be represented as follows:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (1)$$

where η represents the matrix of endogenous variables; B is the matrix of coefficients of the endogenous variables; Γ is the matrix of coefficients of exogenous variables; ξ is the matrix of exogenous variables; and ζ is the matrix of residuals. We simultaneously estimate the parameters B , Γ , and ξ based on the variance-covariance matrix of the observed variables. The assessment of how well the model fits the data relies on comparing the estimated variance-covariance matrix of the observed variables with the actual one. Our approach aligns with the prevailing practice, wherein we estimate SEM models using the maximum likelihood method.

Based on the conceptual model, we tested a series of relationships, as expressed in the following equations:

$$P = \beta_{\epsilon} \epsilon + \beta_{AP} AP + \beta_{CE} CE + z_1 \quad (2)$$

$$\epsilon = \beta_{SoP1} SoP + z_2 \quad (3)$$

$$AP = \beta_{SoP2} SoP + z_3 \quad (4)$$

$$CE = \beta_{SoP3} SoP + z_4 \quad (5)$$

$$SoP = \beta_{TE} TE + \beta_{PM} PM + z_5 \quad (6)$$

where P is academic productivity; IN , AP , and CE is interaction, active participation, and cognitive effort aspects of student engagement; SoP is the variables of sense of place; TE is the travel experience that that are assumed to affect SoP; PM is mode choice between metro and bus; β are the corresponding coefficients; and z are error terms (i.e., residuals).

4. Results

4.1 Descriptive analysis

Transportation mode choices for commuting to the campus are limited to three options: metro, bus, and walking. Interestingly, our survey reveals that 37% of respondents altered their chosen mode of travel following the inauguration of the SCL. To provide a visual representation of these changes, we have depicted respondents' mode choices before and after the introduction of SCL in **Figure 3**. The data indicates that nearly half of the respondents (44%) who previously relied on the bus as their mode of transportation shifted to using the metro after the SCL's launch. Among the respondents, 37% (or 118 individuals) adjusted their mode of travel following the SCL's opening. Remarkably, only a small fraction (16%) of respondents made a change involving the three available categories (bus, metro, and walking). For the subsequent analysis in this study, we primarily focus on public transportation users (bus and metro) and show that students who switched from the bus to the metro generally experienced a stronger sense of place and improved academic performance.

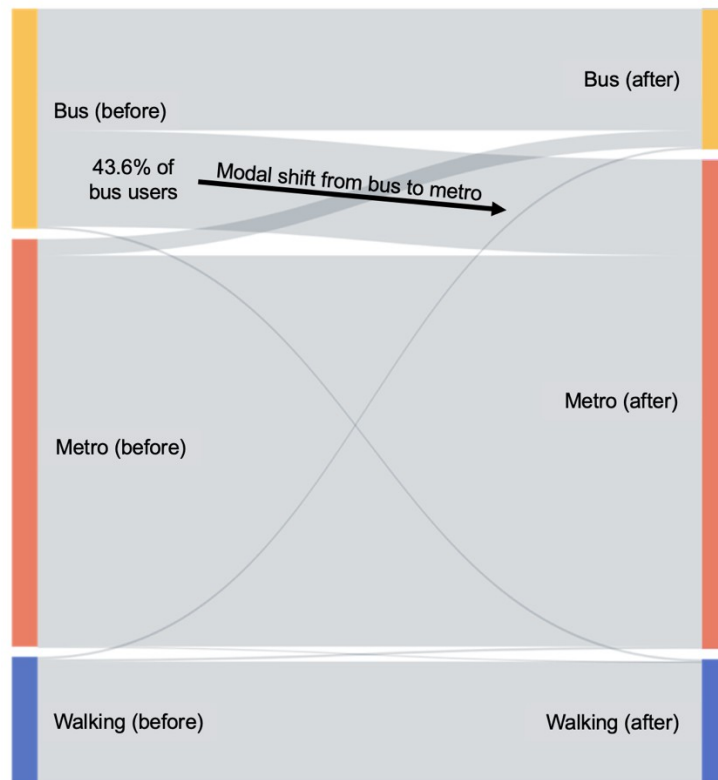


Figure 3 Sankey Diagram of mode shift after the opening of new metro line

4.2 Modeling results

Table 6 and **Figure 4** present the modelling results (standardized regression coefficients or beta). The model fits ($\chi^2 = 443.872$, $p < 0.001$, $df = 158$) suggest that the models give an acceptable representation of the data.

A1 has been partially verified. Regarding the sense of place variables, our regression results demonstrate that travel characteristics have a noticeable impact on variables falling within the categories of place attachment and place identity. The choice of transportation mode does not significantly impact the sense of place. However, negative travel experiences, such as higher travel time, walking and waiting time, seat unavailability, and time uncertainty, significantly influence the sense of place. Notably, the negative coefficient associated with travel time suggests that individuals who have shorter travel times to and from the campus are more likely to attach to their studying place. It is possible that less time spent commuting allows for more time to engage with the local community, facilitate social interactions, fostering a deeper connection to the place and the people within it, and thus contributing to a stronger sense of place (Gerber et al., 2020; He et al., 2021; Miah, 2019). Our findings are consistent with the study conducted by De Vos et al. (2022a), indicating that travel time exerts a more significant impact on satisfaction compared to mode choice. This trend is also evident in the variables related to the distance traveled, although the effect of travel time is more pronounced.

Additionally, a more favorable travel experience, which includes having a seat and spending less time waiting and walking to and from transit stations, is linked to a more comfortable trip and is associated with a more positive perception of the destination (Chan et al., 2022). Notably, the availability of seats significantly influences travel satisfaction (Mouwens, 2015; Wardman and Whelan, 2011), and in urban studies, seat comfort is tied to place attachment (Barron, 2015; Waxman, 2006). Our research aligns with existing literature, indicating that the journey to a place is intertwined with developing a sense of attachment to that place. Conversely, heightened uncertainty, particularly in travel time, diminishes the favorable sense of place for the university campus. Elevated travel time uncertainty negatively impacts accessibility, making reaching destinations less convenient (Chen et al., 2011, 2019; Lee and Miller, 2020). This, coupled with the associated negative emotions and perceived lack of control (Shelat et al., 2021), can taint perceptions, reducing the overall appeal of the destination and contributing to an unfavorable sense of place. Ineffectual and unreliable travel experiences, alongside diminished travel satisfaction, further compound this effect. Drawing on examples, we acknowledge Cresswell

(2023, 2002)'s call to recognize the pivotal role of mobility experiences, not only within a place but also in the journey to a place, shaping our sense of place.

A2 has been verified. When it comes to student engagement, it is evident that a sense of place generally exerts a positive influence, with relaxation having the most pronounced impact. This suggests that students tend to be more engaged when they feel at ease. Our findings resonate with existing literature highlighting how a robust sense of place contributes to enhanced student engagement, achievement, and productivity (Getz and Lev-Ari, 2017; Okoli, 2013). From a transportation and mobility perspective, our study underscores the pivotal role of improved travel experiences in alleviating the cognitive demands associated with commuting. This, in turn, implies higher rates of participation and interaction in class. Furthermore, our research delves into the nuanced effects of place identity on student engagement. Aligning with educational literature that underscores the impact of a sense of community on student achievement (Fong et al., 2023; Shouse, 1996), we extend this understanding to the realm of place, encompassing both fixity and mobility. When students perceive that the place reflects their identity, they are more inclined to participate actively in class. Likewise, when they feel that they can be themselves in that environment, they are more likely to engage in interactions with others. As anticipated, we observe a positive relationship between student engagement and academic productivity. Notably, cognitive efforts emerge as the most influential factor affecting academic productivity.

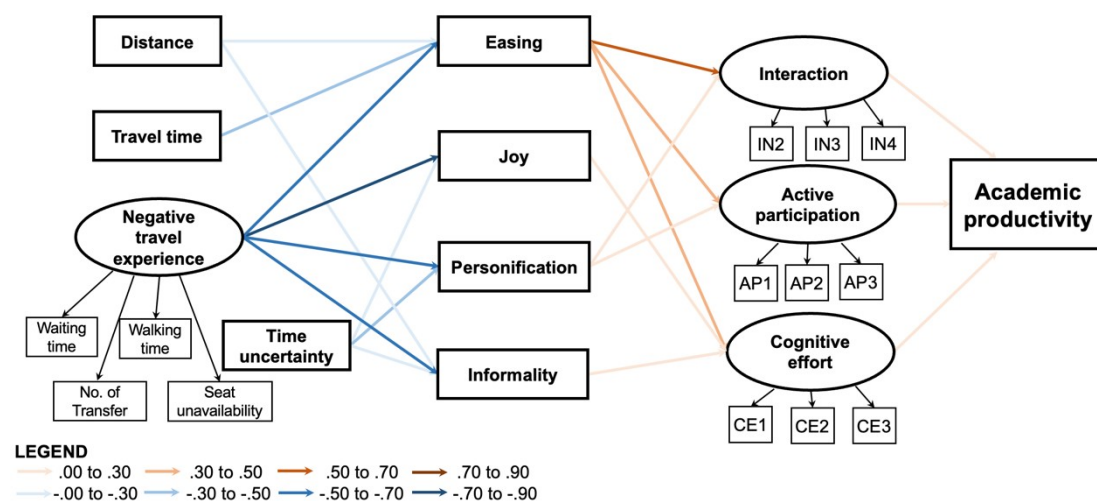


Figure 4 Structural model

Table 6 Modelling results

From	To											
	Sense of place				Transportation mode		Travel characteristic	Travel experience	Student engagement			Academic Productivity
	Easing	Joy	Person	Informality	Metro	Travel time	Uncertainty		Active participation	Interaction	Cognitive Effort	
Sense of place												
<i>Easing</i>									.575***	.390***	.456***	
<i>Joy</i>									.080	-.098	.108**	
<i>Personification</i>									.185*	.180**	.120	
<i>Informality</i>									.206**	-.072	-.074	
Transportation mode												
<i>Metro</i>	.065	.061	.063	.082		.073	-.091	.032				
Travel characteristic												
<i>Travel time</i>	-.436***	.067	.016	-.012								
<i>Uncertainty</i>	-.011	-.287***	-.346***	-.208**								
Negative travel	-.570***	-.719***	-.600***	-.623***								
Travel experience												
<i>Distance</i>	-.137**	-.108	-.007	-.146**	.337***							
Student												

engagement

Participation

.212*

Interaction

.196**

Effort

.264***

Model

summary

<i>R</i> ²	.531	.614	.482	.451	.115	.005	.008	.005	.423	.374	.314	.148
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chi2 = 443.872, p < 0.001, df = 158

Note: *** p < .01; ** p < .05, * p < .1. Variables that lack significant relationships with other variables are not displayed in the table

5. Policy implications

One of the key findings from this study underscores the significant and profound social impact that the introduction of the new metro line had, particularly in terms of the sense of place. These findings hold noteworthy implications for transportation planning and policy. Policymakers and planners can leverage this knowledge to their advantage by investing in the enhancement of the built environment and travel infrastructure around transportation hubs. Such improvements can foster a stronger sense of place among the local population, potentially leading to increased community engagement and social activities. While the study emphasizes the limited impact of the sense of place within a specific station, extending its relevance to other areas magnifies its cumulative significance. Despite challenges in conducting comprehensive assessments and surveys, the study underscores the need for a paradigm shift in estimating broader place effects. This calls for a more reflective methodology in appraising transportation projects, recognizing the wider social impact beyond the sense of place, encompassing mindsets, perceptions, cultural practices, habits, and values. For example, different population groups may hold varying socially constructed narratives about public transportation (Tiznado-Aitken et al., 2020). These narratives can encompass both positive and negative perceptions and may reflect deeper values associated with a particular mode of transport, stemming from its reach and inherent connectivity with meaningful and useful places.

Recognizing that the sense of place is just one aspect of defining and assessing social impacts, transportation planners should actively seek to identify these ‘*deeper*’ factors. This approach allows for a comprehensive understanding of how various transportation interventions and infrastructure changes can lead to profound social consequences. Currently, the field of transportation research and industry exhibits path dependencies towards quantitative modeling and technology in transportation studies and projects (Lowe, 2021; Schwanen et al., 2011). This trend is especially notable in some technocratic countries and cities, such as the US (Lowe, 2021) and Hong Kong (Ng and Wong, 2022).

While these deeper and potentially hidden factors may not be easily discernible, especially through quantitative methods, the results suggest that transportation planners can make headway by focusing on enhancing several aspects of the travel experience and sense of place. Travel experiences, for instance, emerge as a significant aspect that aligns with a recent study by Liu et al. (2023). Their study

highlights how streetscape improvements can promote a sense of place and influence people's choice of transportation modes, particularly encouraging a shift away from car usage toward public and active transportation modes. Additionally, factors like waiting times and seat availability also play crucial roles in creating a positive travel experience. Such experiences are closely tied to the sense of place people associate with their destination. Coupled with the benefits of shorter travel times, providing a convenient and comfortable transportation mode proves pivotal in fostering a sense of place for destinations with social value. It is worth noting, however, that the effects of the transportation mode chosen appear to be insignificant for the community under study. This finding seems to diverge from the case of Santiago (Tiznado-Aitken et al., 2020). This discrepancy might be linked to the place-specific context of Hong Kong's efficient transportation system, where different modes are seamlessly connected between transportation options and destinations (Xue et al., 2012). This observation aligns with our overarching principle of a place-centered approach, emphasizing the importance of acknowledging the influence of place-specific and cultural contexts when evaluating the deeper and wider social impacts of transportation infrastructure.

Given that there is a pre-existing high level of density in Hong Kong, it is important to consider its applicability in other context, for instance, the low-density North American cities. While the Hong Kong model may not be directly replicable in these contexts, the principles of enhancing transit access, reducing reliance on private vehicles, and recognizing the wider social benefits still apply. Nevertheless, strategies need to be adapted to accommodate lower population densities, possibly focusing on place-specific social context and flexibility in providing on-demand services (de Jong et al., 2011). The positive impact on student success, coupled with environmental and economic benefits, provides a multifaceted rationale for cities worldwide to prioritize transit development. This could be especially useful in regions where there may be resistance or a lack of awareness regarding the broader societal advantages of investing in transit. It is also recommended that authorities collaborate closely to establish a well-integrated educational and transportation system that mutually reinforces each other. On the other hand, university students, and students attending higher education in general, constitute a specific social group within the overall population. Policymakers should also delve into the different types of land use connected by transportation infrastructure, considering their deeper and wider social impacts. For example, transportation is often identified as a barrier to social volunteering, a significant contributor to the city's economic vitality (Gil-Lacruz et al., 2019; Taghian et al., 2012). Engagement in such activities is closely tied to the

sense of place (Krasny et al., 2014). Thus, it is imperative to consider the diverse social sectors when evaluating the deeper and wider social impacts of transportation infrastructure.

6. Conclusion

This study delves into the influence of new metro line, more specifically travel experience, on the sense of place—one of the critical elements in defining and assessing social impacts on a location and its communities. In our context of a university community, our regression findings underscore the significant impact of travel characteristics on variables within the realms of place attachment and place identity. Notably, a positive correlation emerges between a sense of place and student engagement, subsequently shaping academic productivity. We contend that expanding the scope of the sense of place effect to encompass other sites, including nearby commercial areas and different stations, amplifies its cumulative significance.

Our comprehensive examination of the social impacts stemming from the SCL project has provided valuable insights, but it is essential to acknowledge the limitations inherent in this study. One notable constraint is our reliance on quantitative methods, Jorgensen and Stedman (2001)'s model, to gauge the strength of the sense of place, measured through factors such as identity, attachment, and dependence. While quantitative approaches are effective in offering measurable indicators, especially for conventional transportation appraisal, they alone fall short of providing a complete understanding of the profound cultural meanings and motivations associated with a person's connection to a place (Jorgensen and Stedman, 2006). While we recognize the limitations inherent in quantitative methods, our goal is to make a meaningful contribution to the quantitative assessment of social impacts, particularly from the perspective of practitioners and policymakers.

To address this gap, the integration of qualitative research methods becomes imperative (Kwan and Schwanen, 2009; Schwanen et al., 2011). Qualitative methods are instrumental in unveiling subjective and contextual aspects that enhance the interpretation of quantitative findings. This approach sheds light on the significance and implications of individuals' relationships with their environment. This, however, raises questions about the suitability of a one-size-fits-all approach in quantifying and holistically capturing the sense of place. Customizing the measurement scale for different population segments—such as those engaged in work or study and those from Western or Eastern backgrounds—may be necessary. It is crucial to note that our

study focuses on a specific community within a defined context and location. Consequently, the methods and tools employed may not be directly applicable for replication in different contexts or with diverse social groups. Nonetheless, as previously emphasized, this underscores the importance for transportation planners to consider the unique characteristics of places connected by transportation infrastructure when assessing social impacts. In light of these considerations, we recommend forging creative connections between critical qualitative and analytical quantitative approaches in modifying the sense of place scale or other scales to capture a wider and more profound understanding of social impacts. This adaptive approach recognizes the need for flexibility in accommodating the nuances of different populations and communities.

Another limitation pertains to the survey data collected, which offers only a brief snapshot of how respondents choose their mode of transportation. This may not accurately represent their long-term travel habits or any changes in their mode selection over time. To gain a more comprehensive understanding of how various factors influence mode choice over time, future studies should employ a longitudinal design. Lastly, our study solely covers the variables that were surveyed and incorporated into our models. It is possible that there are other concealed factors that contribute to travel behaviors, the sense of place, student engagement, and productivity, which were not explored in our research. For instance, other transportation modes such as driving, relevant factors like parking availability, and the wider social context (Chan and Zhou, 2021) were not included in our survey or model. To achieve a more holistic understanding of the intricate relationship between travel behaviors and the deeper values of travelers, qualitative research and potentially a mixed-method approach (Tiznado-Aitken et al., 2020) could be employed to identify these hidden factors.

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