Exploring Space-Time Fixity about Activity Types and Mode Choice

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ABSTRACT

Space-time fixity and flexibility of activity are essential for understanding how space-time constraints influence accessibility and mobility in daily life. Reducing these constraints helps improve quality of life and solve urban problems like traffic jams. Thus, these concepts are vital not only in academia but also in transportation and travel behavior studies. This research explores how activity type and mode choice influence space-time fixity. Descriptive statistics were used to profile respondents and their activities, while bivariate analysis looked at the relationship between mode choice and activity type in terms of space-time fixity. Specifically, mode choices—such as non-motorized, motorcycle, car, public transport, and ride-sourcing—and various out-of-home activities like travel, working/studying, socializing, and grocery shopping. Daily activity data from the Surakarta agglomeration area during the COVID-19 pandemic in 2021 was collected for this study. This study finds that space fixity occurs more often than time fixity, and activities' average level of space and time fixity is fairly flexible. The time fixity pattern for mode choices in out-of-home activities is similar for most activities, except socializing. In contrast, space fixity patterns differ among out-of-home activities. Working/studying outside the home shows the highest time and space fixity across all modes. Research indicates that a score of 6.0 on a 7-point Likert scale represents the highest space-time fixity. This score applies to those who mainly use public transport, with time fixity linked to travel activity and space fixity to out-of-home working/studying activity. The implications of these results on urban planning are discussed.
Keywords: Activity type, COVID-19 pandemic, Mode Choice, Space-time fixity, Surakarta agglomeration area.

ABSTRAK

Kekakuan ruang-waktu (*space-time fixity*) dan fleksibilitas aktivitas sangat penting untuk memahami bagaimana keterbatasan ruang dan waktu mempengaruhi aksesibilitas dan mobilitas dalam kehidupan sehari-hari. Mengurangi keterbatasan ini membantu meningkatkan kualitas hidup dan menyelesaikan masalah perkotaan seperti kemacetan. Dengan demikian, konsep-konsep ini tidak hanya penting di dunia akademik tetapi juga dalam studi transportasi dan perilaku perjalanan. Penelitian ini mengeksplorasi bagaimana jenis aktivitas dan pilihan moda mempengaruhi kekakuan ruang-waktu. Statistik deskriptif digunakan untuk menggambarkan profil responden dan aktivitas mereka, sedangkan analisis bivariat melihat hubungan antara pilihan moda dan jenis aktivitas dalam hal kekakuan ruang-waktu. Secara khusus, pilihan moda seperti non-motorized, sepeda motor, mobil, transportasi umum, dan ride-sourcing, serta berbagai aktivitas di luar rumah seperti perjalanan, bekerja/bersekolah, berinteraksi sosial, dan belanja kebutuhan sehari-hari. Data aktivitas harian dari kawasan aglomerasi Surakarta selama pandemi COVID-19 pada tahun 2021 dikumpulkan untuk penelitian ini. Studi ini menemukan bahwa kekakuan ruang lebih sering terjadi dibanding kekakuan waktu, dan rata-rata tingkat kekakuan ruang dan waktu aktivitas tergolong relatif fleksibel. Pola kekakuan waktu berdasarkan pilihan moda dalam aktivitas luar rumah serupa untuk sebagian besar aktivitas, kecuali aktivitas bersosialisasi. Sebaliknya, pola kekakuan ruang berbeda antar aktivitas luar rumah. Aktivitas bekerja/bersekolah di luar rumah menunjukkan kekakuan waktu dan ruang tertinggi di semua moda. Penelitian menunjukkan bahwa skor 6,0 pada skala Likert 7 poin menggambarkan kekakuan ruang-waktu tertinggi. Skor ini berlaku untuk mereka yang sebagian besar menggunakan transportasi umum, dengan kekakuan waktu berkaitan dengan aktivitas perjalanan dan kekakuan ruang berkaitan dengan aktivitas bekerja/bersekolah di luar rumah. Implikasi dari hasil ini terhadap perencanaan kota juga dibahas.
Kata Kunci: Jenis Aktivitas, Pandemi COVID-19, Pilihan Moda, Kekakuan Ruang-Waktu, Kawasan Aglomerasi Surakarta.

1. Introduction

Transportation systems are more than just a way to travel from one place to another. They are designed to connect people with their destinations, bridging spatial and temporal gaps. The nature of this gap, influenced by the fixed nature of activities, plays a key role in shaping transportation demand and patterns. Proper management of transportation demand and patterns helps improve urban sustainability. Effective management of these factors boosts urban sustainability.

Fixed activities, such as commuting to work, have a big impact on transportation demand and patterns. They need specific infrastructure, like highways and commuter trains, to handle heavy traffic during peak hours. On the other hand, flexible activities encourage the growth of multimodal and decentralized transportation systems, which help spread out demand more evenly over time and in different areas.

Within the framework of time-geography theory, it is recognized that authority constraints play a significant role in influencing activity behavior. On March 11, 2020, the World Health Organization made a pivotal announcement, declaring the coronavirus a global pandemic. The pandemic rapidly spread to over 114 countries, resulting in millions of cases (Matson et al, 2023). In response, numerous affected countries enacted lockdown measures, including stay-at-home orders and limitations on non-essential travel. These measures have shaped authority constraints worldwide, which will change the space-time constraints of individuals and finally change space-time activity.

The enforcement of lockdown regulations worldwide has proven effective in reducing the spread of the COVID-19 (Rajabi et al, 2021) so this regulation is implemented more or less during the pandemic. Lockdown regulations affect various vital sectors, i.e., industry, health, transportation, and education (Rajabi et al, 2021). Travel behavior has turned due to movement limitations, affecting the trips frequency, choice of mode, route selection, and trip distance (Politis, 2021; Abdullah et al, 2020; Hook et al, 2021; Zhang, 2021). This change in travel patterns significantly reduces the amount of traffic volume by as much as during the COVID-19 pandemic (Politis, 2021; Katrakazas, 2020). Reducing traffic is evidenced by the increase in speed on urban roads, which can be interpreted as reduced congestion (Li et al, 2021).

Conversely, the pandemic's effect on travel behavior has intricate environmental and equity consequences. Telecommuting can decrease vehicle mileage and greenhouse gas emissions linked to commuter travel (Shamshiripour et al, 2020). It can significantly alleviate congestion during peak hours (Matson et al, 2021).

In Indonesia, the implementation of lockdown and social distancing policies under the Large-Scale Social Restriction (PSBB) regulation began on March 31, 2020. The PSBB included measures such as school and work holidays, restrictions on religious activities, and limitations on public gatherings and use of facilities. This was based on government regulation Peraturan Pemerintah Nomor 21 Tahun 2020. Thanks to effective treatment and regulation, the spread of the COVID-19 pandemic decreased significantly. Consequently, the Indonesian government transitioned to an emergency policy called Pemberlakuan Pembatasan Kegiatan Masyarakat Darurat (PPKM), which aimed to further manage community activities. The PPKM regulations are based on the level of spread of Covid-19. Emergency PPKM contains work activity instructions 75% Work from Home (WFH) for non-essential fields, 100% study from home (SFH), for celebration activities community at most 25% of capacity and no food on-site, supermarkets/hypermarts close at 17:00 WIT (Instruksi Menteri Dalam Negeri Nomor 17 Tahun 2021).

The implementation of PSBB and PPKM significantly limits community activities, affecting the type of activity, when, where, and the involvement of other people. Previous research further explains these restrictions, which concluded that the fixity level is intricately tied to the activity's attributes. These attributes involve the type of activity, timing, location, duration, the participation of others, and factors such as the background of the person initiating the activity. Personal factors, such as gender, also play a significant role in this analysis (Schwanen et al, 2008). Therefore, implementing the lockdown policy changes the space-time constraints and alters the space-time activity.

Exploring the factors influencing space-time fixity can deepen our understanding of the concept. This research examines how various activity types and mode choices influence space-time fixity. Since space-time fixity is affected by space-time constraints, which influence accessibility and mobility, the findings aim to provide recommendations for enhancing individual accessibility and mobility during pandemics.

1.1 Space-time Fixity

Time-geographic concepts clearly demonstrate that a daily of person's of activities and trips can be effectively featured by a path in space-time, shaped by a definite set of constraints within a 'prism' (Hägerstrand, 1970). Some activities have a high level of fixity in time and space, which limits a person's choices to those that can occur within the constraints of these fixed activities. Activities with a high spatial and temporal fixity level serve as "pegs" around which other activities are managed. Spatial constraints are more common, but temporal fixity also

significantly affects the overall scheduling of activities (Burnett, 1980; Cullen & Godson, 1975). Numerous studies address this theme, as space-time fixity can enhance planning strategies and public policies, improve people's quality of life, and tackle urban issues (Shen, 2015).

Kwan's study investigates the constraints of space and time, emphasizing the importance of time budget constraints and fixity constraints as critical variables. The research identifies that time budget constraints result from the narrow time available to individuals, following accounting for fundamental daily activities, such as sleep. Additionally, work commitments are considered, as both spatial and temporal fixity significantly limit the time available for discretionary out-of-home activities. Furthermore, the concept of fixity constraint pertains to the rigidity of time and space associated with these out-of-home activities. Based on this framework, the study concludes that space-time constraints have a notable influence on individuals' activity and travel patterns (Kwan, 200). The results obtained align with prior research, demonstrating that the spatial and temporal consistency of specific out-of-home activities, such as serving passenger trips, plays a pivotal role in influencing an individual's activity-travel patterns (Kitamura & Kermanshah, 1983).

Several studies investigate time-space constraints by analyzing the spatial and temporal fixity of everyday activities. These studies explore the relationships between varying levels of space-time fixity and the characteristics of both activities and individuals (Cullen & Godson, 1975; Kwan, 2000; Doherty, 2006). Several factors influence the levels of fixity, including the type of activity, the timing, the location, the duration, the individuals involved, and the background of the person initiating the activity (Schwanen et al, 2008). A previous study looked at how household structure affects gender differences in space-time constraints when people do daily activities. It found that these constraints can change based on whether a person is male or female and how their household is set up. The results show that both gender and household structure are important. When retired parents provide help, they can reduce the challenges that household heads face and lessen the gender differences in space-time constraints. However, the level of help provided varies by activity and the age of the retired parents. Additionally, an individual's background and their household situation influence the level of constraints they experience while starting an activity (Kwan et al, 2015).

Another exciting issue discussed is the measuring tools of space-time constraints, partly because of the data limitations (Schwanen et al, 2008; Kwan, 2000). Schwanen describes a method to measure space-time constraints by looking at how out-of-home activities are fixed

in time and location. This method identifies which activities create space-time constraints for people in their daily lives from a time-geographic viewpoint. To understand how flexible people feel about their activities in terms of time and space, researchers asked a series of questions – for example, "How easy is it for you to change the time of day for this activity/trip?" and "How easy is it for you to change the place for this activity?" (Schwanen et al, 2008; Kwan, 2000). Finally, a scientist suggests a definition of fixed activity as an activity that cannot be easily rescheduled or relocated (e.g., work, meetings). In contrast, flexible activities can be more easily rescheduled and/or occur at multiple locations (e.g., shopping, recreation) (Miller, 2017).

1.2 Activity Types

Activity type is a part of activity attributes. Exploring the attributes of activity has been discussed for almost five decades. The earlier study about the structure of activity patterns suggests that the attributes of activities consist of space and time fixities, participant group, location, priority, activity type, and duration (Burnett, 1980). Another approach includes nine attributes to design simulation experiments on activity scheduling behavior; it covers the spatial configuration of the schedule, the time spent on activities, the percentage of scheduled activities, the location of activities in the schedule, the locations of activities not yet scheduled, the attractiveness of the locations visited, the total travel time implied by the schedule, the latest possible finishing times of the scheduled activities, the length of open slots in the schedule, the chance of completing the schedule (Ettema, 1993), and there exist any other approaches that proposed by the scientist. Based on the literature review, activity attributes are co-evolved with the context in which they occur. They may be systematically related to attributes of the activity itself and the background of the person undertaking it (Schwanen et al, 2008). Hence, the activity attributes are not the same among studies.

Out-of-home activity refers to various daily tasks performed outside the home as it's typically understood. However, 'home' can also include the social networks and relationships vital for household support at the neighborhood level. Out-of-home activities have become increasingly significant in structuring roles in individuals' everyday lives. One reason for this phenomenon is that the fixed nature of certain out-of-home activities, such as serving passenger trips, is a critical factor influencing an individual's activity-travel patterns. A review of this topic reveals a significant correlation with women, indicating that they are often primarily responsible for the majority of out-of-home household-related activities and travel. The distribution and execution of these tasks play a crucial role in the gender division of domestic labor. The spatial and temporal demands of women's activities outside the home significantly

influence their job status and the distances they travel for commuting. Additionally, the rigor of these activities contributes to daily stress for women (Kwan, 2000).

Daily activities can vary greatly, so it's important to group them into broader categories. We can categorize activities in different ways, such as by using what people say about them or by applying theories. One way is to look at daily social tasks in three main areas: work, childcare, and maintaining the household. However, this method has some drawbacks. The way someone describes an activity may not reflect its main purpose since the same activity can serve different goals. For instance, a shopping trip might be mainly for socializing or recreation. Additionally, it can be hard to create categories that match how people truly feel about an activity because opinions can differ widely. Recognizing these issues, a study on gender differences in how people manage their time grouped out-of-home activities based on the main purpose that people described. This way, they used individuals' own feelings to better define each activity (Kwan, 2000). The following are the five main objectives of activities: (a) employment or employment-related activities; (b) fundamental household needs- grocery shopping for household needs; dropping off or picking up a child at childcare or school; accompanying a child to dance class; and the other more.; (c) personal needs- banking, visiting a doctor, visiting a library or public office, mailing letters and packages, taking the car to repair, hairdressing, and more.; (d) pleasure, leisure, or recreational activities class, such as bowling, horseback riding, movies, and others.; and (e) social activity with friends and/or visiting friends and family members, attending church or other social events, and others more (Kwan, 2000). A previous study focused on older adults' unmet activity needs and well-being concerning the types of group activities they engage in. It examines the most common activities in the daily lives of older people and how they address the dimensions of 'having,' 'loving,' and 'being' as defined by Allardt (Nordbakke and Schwanen, 2014). Grouping activities can be done by considering the correlation approach to other variables discussed.

1.3 Moda Choice

Previous studies indicate that sociodemographic characteristics and travel attributes, such as age, gender, educational level, car ownership, and travel time, influence mode choice in travel (Kalter, 2021; Meng et al, 2018). The results of Miller's research support the space-time prism concept, indicating that limitations on human activities in both physical and virtual environments can influence activity-travel behavior (Miler, 2017). Car ownership is a part of personal capabilities, which are part of the human activity constraints that affect activity-travel behavior, particularly the choice of transportation mode. These constraints are essential

variables affecting how people travel and engage in activities. However, it is also necessary to recognize that mode choice can, in turn, shape these constraints. Recognizing that space-time fixity is a part of space-time constraints, which are components of human activity constraints, indicates that mode choice influences space-time fixity.

Existing studies on the influence of car ownership on mode choice present inconsistent results; most studies indicate that car ownership significantly affects mode choice. However, a few studies suggest that car ownership does not substantially impact this decision (Kalter, 2021). Considering these varying findings, it is worth hypothesizing in a different direction: that mode choice may, in fact, influence space-time fixity.

2. Materials and Method

This study employed quantitative analysis to determine and characterize space-time fixity differences according to activity type and mode choice. Mode choice influences space-time fixity for various out-of-home activities. A household interview survey was conducted to gather data on daily activities and their levels of space-time fixity across different activity types..

2.1 Study Area

Surakarta, located in Central Java province in Indonesia, is surrounded by four regions. Although it has a smaller area than these other regions, as shown in Figure 1, the city has a strong appeal that attracts visitors. As a result, the border areas of Surakarta can be integrated into a single region. Even though these areas are administratively distinct, they can collectively be defined as the Surakarta Agglomeration Area (SAA).

Figure 1. Location of the study

2.2 Research Data

The study location is the Surakarta agglomeration area. Data was collected in 2021 through the COVID-19 pandemic through household interviews with an Indonesian questionnaire. It covers socio-demographics, daily activities (activity types), mode of transportation, and the space-time fixity of these activities. Data were recorded in 15-minute intervals for four days: Sunday, Monday, Tuesday, and Wednesday, involving respondents aged 18 and older.

Data will be collected through a closed-ended questionnaire that features ordered-choice questions, thereby enhancing the objectivity of the measurements. Space-time fixity will be evaluated using a 7-point Likert scale, with the endpoints ranging from "very flexible" (1) to "very fixed" (7). The categorization of activity types is presented in Table 1.

Table 1. Activity type classification

In-home Activity (Notation)	Out-of-home Activity (Notation)
In-Home Mandatory (IhMo)	Out-of-home online resting activities (OhOna)
In-Home Maintenance (IhMt)	Out-of-home offline resting activities (OhOfa)
In-home offline leisure (IhLe)	Out-of-home socializing/recreation (OhSoRe)
In-home online activity (IhOa)	Out-of-home household activities (OhHa)
In-home working and studying (IhWoSy)	Out-of-home babysitting (OhBs)
In-home sport (IhSpt)	Out-of-home working and studying (OhWoSy)
	Grocery shopping (OhGs)
	Online shopping (OnSh)
	In-store shopping (InSh)
	Out-of-home sport (OhSpt)
	Out of Home Maintenance – Other maintenance (OhOM)
	Picking and dropping children (OhPc)
	Travel

Given population size and demographic characteristics, norms and culture determine human activities and travel behavior. Population characteristics include variations in gender, age, occupation, and income. This significant variable performs a unique community in an area that affects activity-travel behavior. As shown in Table 2, the sociodemographic composition of males and females is almost balanced. The age composition between 18 - 22, 23 - 45, and 46 - 55 years is nearly the same; the lowest range is above 55. Human needs and desires are significantly influenced by socio-economic and cultural factors. The composition of the occupations was dominated by workers at 50,50%, followed by students and non-workers at 29,10% and 20,40%. Even the highest occupation percentage is worker, but the income composition is dominated by low income at 37,25%, high income at 33,33%, and medium income at 29,41%. This shows that a worker's salary is relatively low within this study location.

According to the ANOVA single-factor analysis, the mean values of space fixity and time fixity are significantly different, with the mean value of space fixity being greater than that of time fixity. This research result supports previous findings that indicate space fixity occurs more frequently than time fixity (Schwanen et al, 2008; Shen et al, 2015).

Table 2. Sociodemographic and activity fixity profile

Variable	Frequency (Percentage)	Mean
Sociodemographic characteristics		
Gender		
Male	200 (49.75%)	
Female	202 (50.25%)	
Age		
18 - 22 years	117 (29.10%)	
23 - 45 years	109 (27.11%)	
46 - 55 years	110 (27.36%)	
Above 55 years	66 (16.42%)	
Occupation		
Non-worker	82 (20.40%)	
Worker	203 (50.50%)	
Student	117 (29.10%)	
Income		
Low income (< 3 million IDR/month)	145 (37.25%)	
Medium income (3–6 million IDR/month)	121 (29.41%)	
High income (> 6 million IDR/month)	136 (33.33%)	
Space-time fixity of all activity types		
Space fixity		3,37*
Time fixity		3,24*

*Space-time fixity is measured with a 7-Likert scale

2.3 Analysis Methods

Descriptive statistics were employed to profile the respondents and their activity attributes effectively. In conjunction, Anova was conducted to explore the relationship between mode choice and activity type, specifically in the context of space-time fixity. This approach provides valuable insights into how mode preferences relate to different activities across time and space.

3. Result and Discussion

Figure 2 illustrates the levels of space-time fixity of activity during the COVID-19 pandemic. It found that 24.8% of individuals displayed very fixed, fixed, and fairly fixed levels

of space fixity, while 23.3% exhibited similar levels of time fixity. Most participants, however, fell into a category classified as fairly flexible for time and space fixity.

In contrast, a previous study conducted in Columbus, Ohio, in 2008 under normal, unrestricted conditions using a 5-point Likert scale found that 62.9% of respondents reported experiencing difficult or very fixed levels of spatial fixity, while 47.3% reported similar feelings regarding time fixity [13]. By comparing these findings through statistical descriptive analysis from both the COVID-19 pandemic and normal conditions, it can be concluded that activities during the pandemic were generally more flexible than normal conditions in terms of space and time.
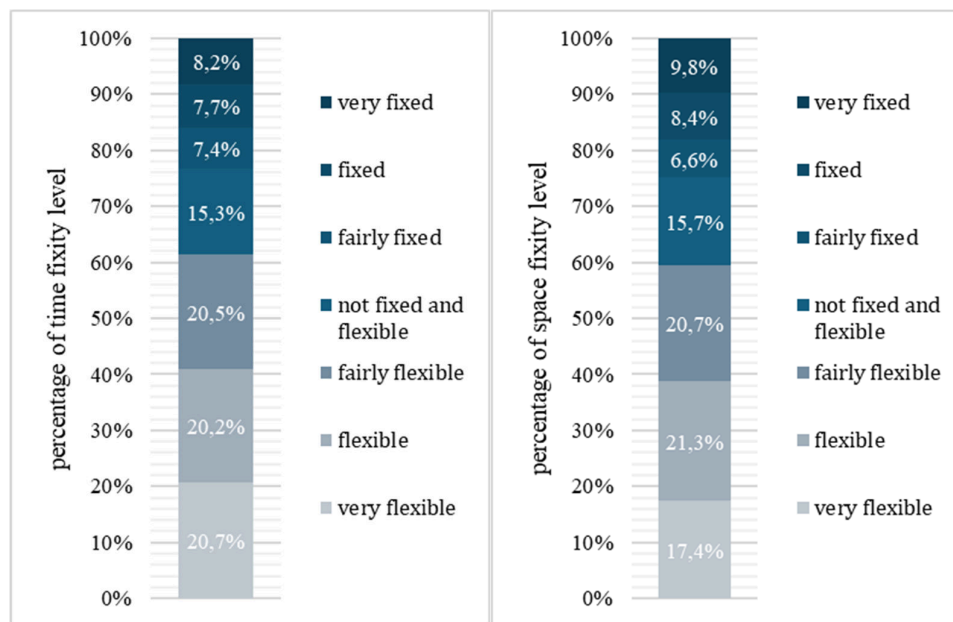

Figure 2. Space-time fixity composition

3.1 Space-Time Fixity Based on the Effect of Activity Type

This study allocates daily time for various activities based on the Amirotul study [28]). Most of the time was devoted to mandatory in-home (IhMo) activities, while the least time was spent on online shopping (OnSh). Additionally, during the implementation of movement limitations, the time duration for out-of-home working/studying is longer than for in-home working/studying.

The trends between space and time fixity levels among activity types differ, as shown in Figure 3. The highest time fixity level is for out-of-home babysitting (OhBs), while the highest space fixity level is for out-of-home picking up and dropping off the children (OhPc). The

lowest space fixity level is for in-home sports (IhSpt), while the lowest time fixity level is for online shopping (OnSh).

The space-time fixity level of out-of-home and in-home activities during the COVID-19 pandemic is a novel finding. It is revealed that most out-of-home activities, except shopping, have a higher fixity level than in-home activities. When it comes to shopping, the space fixity of in-store shopping is more flexible than that of online shopping. Shopping activity is contradictory to working/studying and grocery shopping. This result indicates a new understanding of consumer behavior that underscores the need for further, in-depth study.
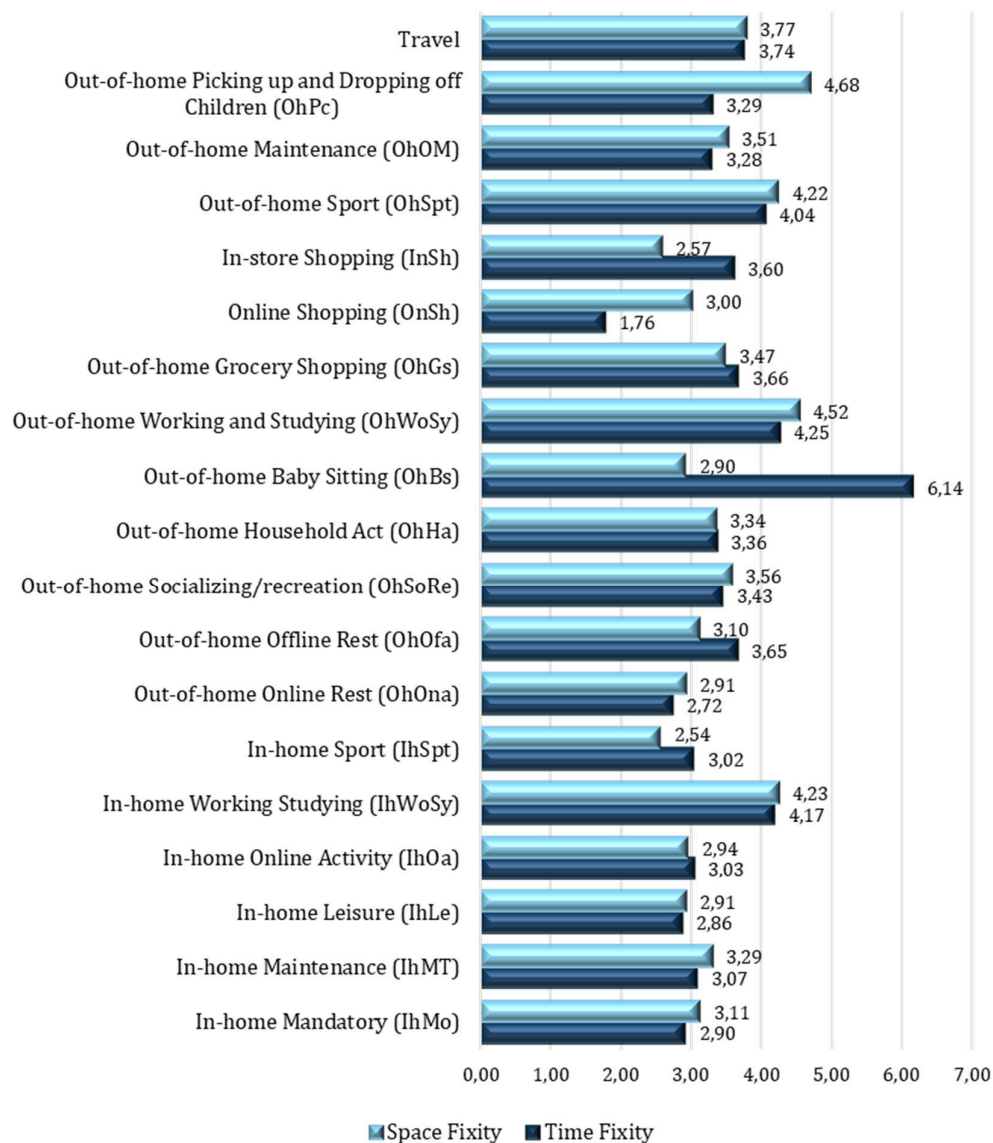

Figure 3. Space-time fixity based on activity type

In 2008, a 5-point Likert scale was utilized to assess space-time fixity levels under normal conditions in Ohio, USA (Schwanen et al 2008). The findings indicated that the time fixity score

for working was 4.25, suggesting it was "fixed," while for studying, the score was 3.74, indicating it was "rather fixed." Regarding space fixity, the scores were 4.69 for working, indicating it was "fixed," and 3.65 for studying, suggesting it was "rather fixed." For other activity types analyzed in this study, the space-time fixity in Schwanen's study results was "fixed."

In contrast, in this study, during the 2021 pandemic, a 7-point Likert scale was employed to measure time fixity levels in Surakarta, Indonesia. As shown in Figure 3, the time fixity score for out-of-home working or studying was 4.25, indicating it was "not fixed and flexible." The space fixity score was 4.52, suggesting it was "not fixed and flexible." This study result differs from Schwanen's study result. Furthermore, in this study, most activities related to space-time fixity were found to be "fairly flexible."

The COVID-19 pandemic has brought significant changes to various aspects of transportation, including mobility, travel behavior, road safety, and traffic volume (Barbour et al, 2021; Matson et al, 2021). The results of this study bolster that COVID-19 has impacted behavioral patterns, specifically in relation to space-time fixity. The data indicate a trend toward increased flexibility in these behaviors compared to pre-pandemic conditions. The effect of lockdowns and movement restrictions on fixity has not been as significant as the concerns regarding infection risk and the allowance to work and study from home. It is also understood that utilizing online communication tends to decrease spatial-temporal fixity. Thus, individuals have adapted their behavior to the restriction of movement and social distancing policy by implementing online activity.

3.2 Space-Time Fixity Based on the Effect of Mode Choice

This research has analyzed five modes of transport: private and public transport. Despite some capacity and time restrictions, public transport facilities, such as mini and extensive buses, operated during the COVID-19 pandemic. We call ride-sourcing for taxis and ridesharing, which are booked online.

Under normal conditions, the main factors influencing transportation mode choice include travel time, convenience, trip cost, space and privacy, congestion avoidance, risk of infection, sustainability, and social status. However, during the COVID-19 pandemic, the severity of illness caused by the virus significantly changed the order of these factors. Notably, recent research in Ohio, USA, found that the risk of infection became the top concern (Palma et al, 2022), providing a specific example of this shift in priorities.

Figure 4 shows the composition of modes used based on travel time duration in Surakarta Agglomeration Area. The most desired mode is the private car, 55.51%, and this result supports previous research for American workers commuting in Ohio, USA, 44.0% [29]. Palma's research also states that the key reason for transportation mode choice during the COVID-19 pandemic is the risk of infection (Palma et al, 2022), as we know, private cars are the least likely to be infected. Reducing the risk of infections influenced transportation choices, leading to a significant decline in public transportation usage due to the heightened risk of virus exposure. Only 1.83% used buses, and 0.46% used ride-sourcing in Surakarta Agglomeration Area.
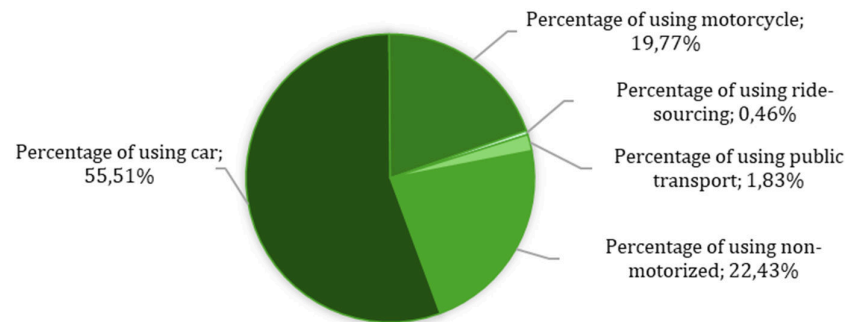

Figure 4. Travel time percentage of using mode

The bivariate analysis is a valuable tool for understanding how choices of transportation modes influence space-time fixity. This analysis has yielded several important findings, illustrated in Figure 5 and based on activity type classifications presented in Table 1.
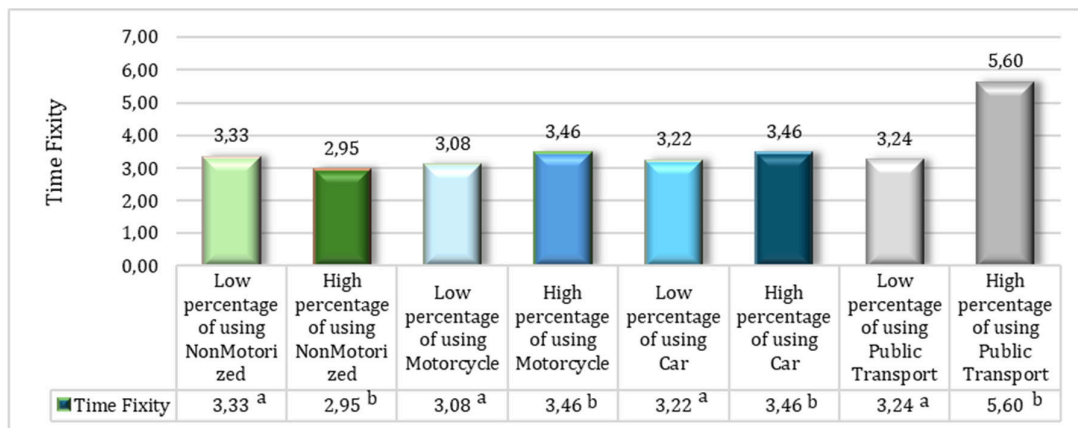

Figure 5. Time fixity level based on a percentage of using mode

One notable observation is that the average time fixity for individuals using ride-sourcing services remains consistent, regardless of whether they use these services frequently or infrequently. In contrast, time fixity varies greatly among other transportation modes.

Specifically, those who primarily use public transport show the highest level of time fixity, while individuals relying on non-motorized modes display the greatest flexibility in terms of time.

During a pandemic, public transportation faces time and capacity limitations. Capacity is reduced, and operational hours are shortened to help prevent the spread of the virus. Therefore, it makes sense that public transportation has the highest time fixity, as these restrictions increase constraints. On the other hand, non-motorized modes of transport, often used for short-distance travel as part of private transportation, are not subject to time constraints. As a result, they have the most time flexibility.

Figure 6 illustrates the level of space fixity based on the percentage of usage for different modes of transportation. A notable finding is that the average space fixity values for public transport and ride-sourcing are similar, regardless of how long they are used. This observation is particularly interesting. In contrast, the average space fixity values for other modes vary significantly.
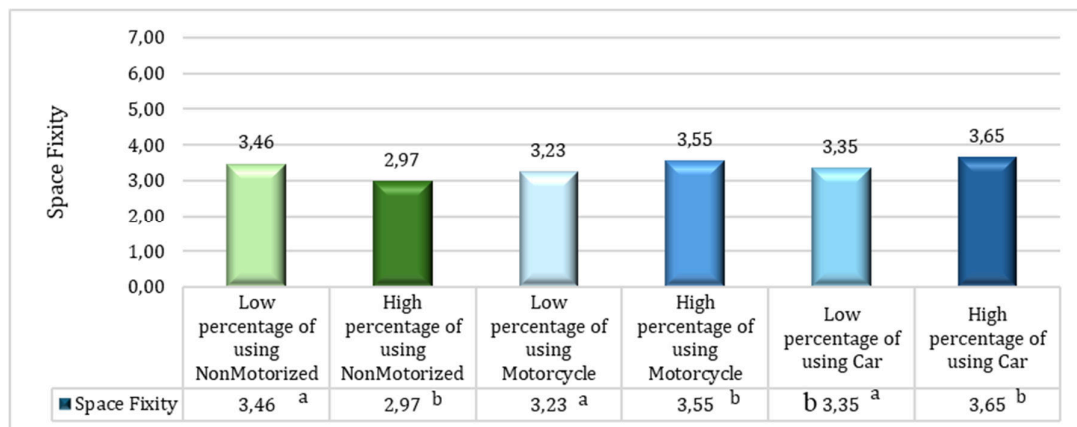

Space Fixity	Low percentage of using NonMotorized	High percentage of using NonMotorized	Low percentage of using Motorcycle	High percentage of using Motorcycle	Low percentage of using Car	High percentage of using Car
	3,46 a	2,97 b	3,23 a	3,55 b	b 3,35 a	3,65 b

Figure 6. Space fixity level based on a percentage of using mode

Figure 4 demonstrates that the usage rates for public transport and ride-sourcing are quite low, at 1.83% and 0.46%, respectively. Recent research backs this finding, suggesting that these transportation options have seen a significant decline due to less frequent service and users' worries about the risk of virus transmission in shared vehicles [30]. Recent research findings underline the credibility of this information.

3.3 Space-Time Fixity Based on the Effect of Activity Type and Mode Choice

Figure 7 shows how different transportation modes affect time fixity for various out-of-home activities, such as travel, working/studying, socializing, and grocery shopping. The time fixity patterns, which refer to how difficult it is for people to change the timing of activities, are

quite similar for three activities: travel, grocery shopping, and working/studying outside the home. Out-of-home working/studying has the highest time fixity, meaning people find it hard to change the timing of these activities. This is because out-of-home working/studying is a necessary activity tied to responsibilities, basic needs, and income. On the other hand, the time fixity levels for travel and grocery shopping show similar trends and almost the same values, suggesting that people have preferred times for these activities. Grocery shopping, being a discretionary activity, is based on personal choice and preference rather than necessity.

Individuals who heavily rely on public transport show a notably higher level of time fixity in their travel and out-of-home activities compared to users of other transportation modes. This is due to the constraints of public transport during the COVID-19 pandemics. Although the operational hours during the COVID-19 pandemic remained normal, 05:00-21:00 WIT, the government reduced the public transport capacity to 50%. This limitation inflicts time fixity. To reduce time fixity due to public transport capacity reduction so the public transport frequency needs to be increased. Other factors that support the time fixity for public transport modes are fixed schedules, waiting times, and longer travel durations compared to other modes. When comparing individuals with low and high usage of each mode, those who spend more time using a specific mode generally have higher time fixity, except for non-motorized transport users.

Socializing activities are considered fairly flexible, meaning they are not mandatory. This flexibility allows individuals to choose when and how to participate. Additionally, using private transportation options like motorbikes and cars can enhance the experience, adding an element of curiosity while still serving the purpose and urgency of the activities. Embracing this freedom can lead to more enjoyable and meaningful social interactions.
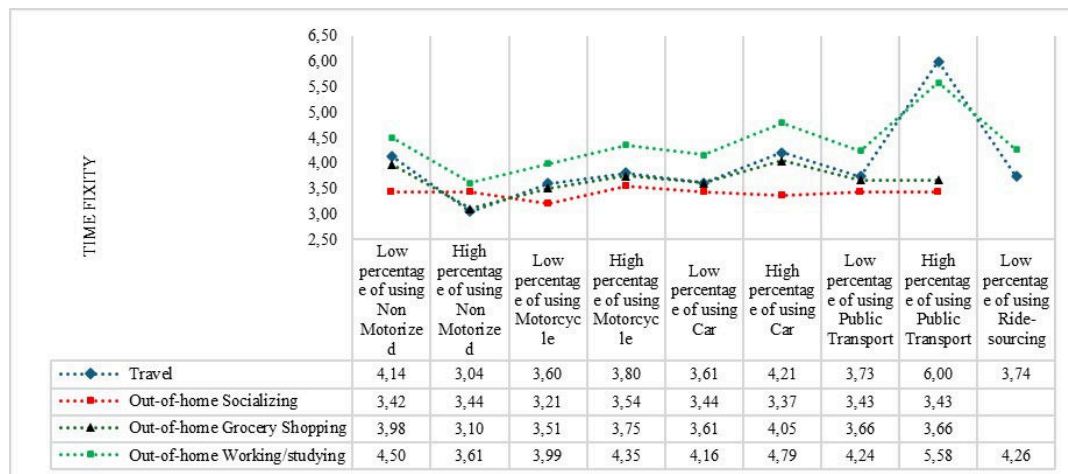

	Low percentage of using Non Motorized	High percentage of using Non Motorized	Low percentage of using Motorcycle	High percentage of using Motorcycle	Low percentage of using Car	High percentage of using Car	Low percentage of using Public Transport	High percentage of using Public Transport	Low percentage of using Ride-sourcing
Travel	4,14	3,04	3,60	3,80	3,61	4,21	3,73	6,00	3,74
Out-of-home Socializing	3,42	3,44	3,21	3,54	3,44	3,37	3,43	3,43	
Out-of-home Grocery Shopping	3,98	3,10	3,51	3,75	3,61	4,05	3,66	3,66	
Out-of-home Working/studying	4,50	3,61	3,99	4,35	4,16	4,79	4,24	5,58	4,26

Figure 7. Time fixity level based on use percentages of modes and out-of-home activities.

The chart illustrates the impact of various transportation modes on the space fixity of different out-of-home activities. These activities include travel, working or studying outside the home, socializing, and grocery shopping, as shown in Figure 8. Interestingly, out-of-home working/studying shows the highest level of space fixity across all transportation modes.

Surakarta has an area of 44,1 km2. Land use in Surakarta is urban sprawl, emphasizing the need to provide space for gardens and family needs. This means that the locations where individuals work and study are not close to individuals' residences. In 2021, Surakarta had four public transport (Batik Solo Trans) corridors with six feeders. Batik Solo Trans services only a few places and misses many regions, including work/study places. It makes sense for individuals in Surakarta who have a high percentage of using public transport to have high space fixity. This finding is important because it suggests that when people engage in these activities away from home, their locations are harder to change compared to other activities, offering useful insights for urban planning and transportation studies to develop the transit network.

Our research emphasizes the need to further explore the connection between space fixity and reliance on public transport. We found that individuals who rely heavily on public transport experience a much higher level of space fixity in their travel and out-of-home working/studying activities compared to those using other transportation modes. It is essential to understand that the connection between time usage and spatial fixity varies among different activities and modes. This indicates that additional research in this area is necessary.
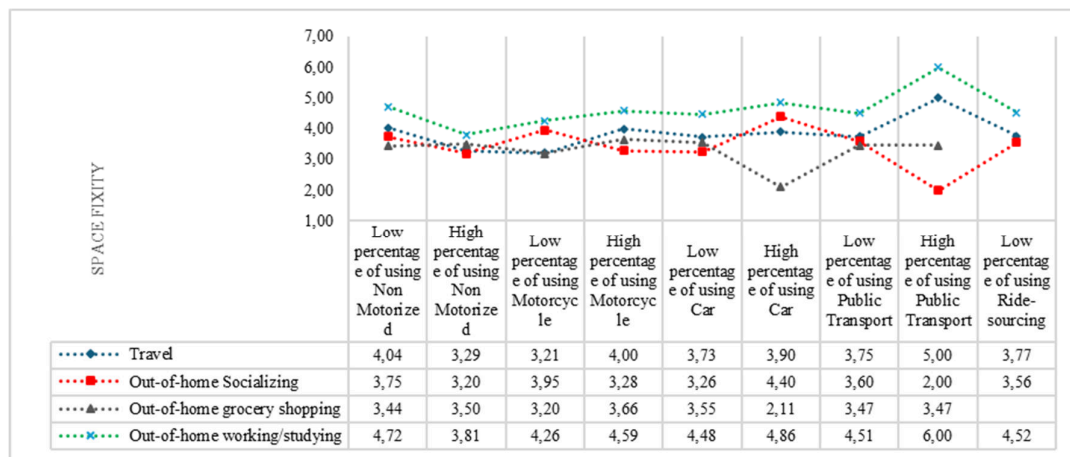

	Low percentage of using Non Motorized	High percentage of using Non Motorized	Low percentage of using Motorcycle	High percentage of using Motorcycle	Low percentage of using Car	High percentage of using Car	Low percentage of using Public Transport	High percentage of using Public Transport	Low percentage of using Ride-sourcing
Travel	4,04	3,29	3,21	4,00	3,73	3,90	3,75	5,00	3,77
Out-of-home Socializing	3,75	3,20	3,95	3,28	3,26	4,40	3,60	2,00	3,56
Out-of-home grocery shopping	3,44	3,50	3,20	3,66	3,55	2,11	3,47	3,47	
Out-of-home working/studying	4,72	3,81	4,26	4,59	4,48	4,86	4,51	6,00	4,52

Figure 8. Space fixity level based on use percentages of modes and out-of-home activities.

4. Conclusions

During the COVID-19 pandemic, activities' average level of space and time fixity is fairly flexible. The average space fixity was slightly higher than time fixity, indicating that space

fixity occurred more frequently than time fixity. Spatial fixity constraints were more frequent, but temporal fixity significantly impacted the overall activity scheduling process. The highest level of time fixity is for individuals with a high percentage of using public transport, it could be because of low frequency, and longer durations of public transport. Thus, urban planners could consider reducing the limitation of operational hours and frequency of public transport during a pandemic.

The space-time fixity levels for out-of-home and in-home activities during the pandemic reveal new insights. Overall, various activities' space-time fixity was more flexible than usual, unrestricted conditions. This means that the implementation of social distancing and movement restriction bargains with the implementation of online activity reduces space-time fixity. Individuals are more aware of the risk of COVID-19 infection. Thus, individuals adapted their behavior to movement restriction and social distancing policies during a pandemic concerning activity based on purpose.

Trends in space and time fixity varied among different types of activities. Most out-of-home activities, except shopping, exhibited more fixity than in-home activities. Additionally, when examining shopping behaviors, we found that the space fixity associated with in-store shopping was more flexible than that of online shopping, which challenges our previous understanding of consumer behavior.

The patterns of time and space fixity in various out-of-home activities -such as travel, grocery shopping, and working/studying- vary. It finds that out-of-home working/studying has the highest time fixity due to its mandatory nature, while grocery shopping shows similar but lower levels as discretionary. Socializing is more flexible, allowing individuals to choose their involvement. The analysis of transportation modes reveals that out-of-home working/studying also exhibits the highest space fixity, with significant implications for urban planning. Understandably, individuals struggle to adjust their activity locations to align with transit networks, mainly when working or studying, and they are often tied to permanent organizations. This situation highlights a connection between mode-specific constraints and spatial fixity. The need to develop the public transport network in the Surakarta agglomeration area is underscored to reduce the spatial fixity of out-of-home working/studying activity during a pandemic.

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