Mapping the Time Use Research Field in the Context of Sustainability: Network Analysis and Scoping Review

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The field of time use research has witnessed a continuous growth in recent decades. Meanwhile, the sustainability discourse also began to incorporate the time use approach. However, there is minimal research about the underlying knowledge base of the time use field, which creates difficulty for sustainability time-use studies to position themselves, draw insights from other disciplines, or achieve a comprehensive understanding of how human time allocation informs sustainability concepts and methods. This thesis established the first attempt to map the field of time use research, with the combination of co-citation network analysis and qualitative scoping review. We also explored a new bibliometric method, termed as "content-similarity network analysis". The triangulation allowed us to identify convergent themes, such as household economics and well-being, sexual division of labour and child care, consumer behaviour, as well as transportation, underpinning this inter- and multi-disciplinary field. After the content-similarity network being generated based on the abstracts, we were able to investigate the relationship between household energy use and time use. Further, we created a conceptual framework to describe how the time use research can help approach the sustainability issues. It is shown that time use data, complementary to monetary and biophysical data, has the potential to enrich the social and behavioral aspects of sustainability. Our results also suggest an under-representation of sustainability themes in the time use field. By reinforcing the importance of knowledge integration across disciplines, this thesis adds to the growing body of sustainability literature at the interface of ecological economics, well-being, consumer-lifestyle, and urban planning.

Keywords: time use research, energy, sustainability, co-citation network analysis, content-similarity network analysis, scoping review

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1. Introduction

1.1 Transcending the disciplinary silos: time use and sustainability

Time is a finite and an equally-shared resource. Everyone has and only has 24 hours per day. Therefore, time is a scarce resource needed for numerous activities. From an individual point of view, time is devoted to paid work, housework, personal care, and leisure. From a systematic (socioecological) perspective, human time, along with biophysical and monetary resources, is required to sustain and reproduce systems of different levels: self, household and family, community, and economy at large (Fischer-Kowalski et al., 2010; Ringhofer, 2010). At both micro- and macro-levels, human time use is an important descriptive and analytical tool: how people use their time can help understand individual behaviour changes, measure quality of life or general well-being, complement traditional economic accounts, analyze socioecological transitions etc. (Fischer-Kowalski et al., 2010; Fleming & Spellerberg, 1999; Gershuny, 2000; Harvey & Pentland, 1999; United Nations, 2005). Time use surveys or diaries, which document periodic activities and how much time is spent on each of the activities, are “quantitative summaries” of people’s life (United Nations, 2005, p.5). Built upon the richness of these data, time use research has been growing into an inter- and multidisciplinary field.

Household economists conceptualize “time” as an input resource combined with goods and services to maximize household utilities (Becker, 1965). Bringing in more consideration of the human agency, sociologists and psychologists are interested in topics such as the sexual division of labour (e.g., Bittman & Wajcman, 2000; Craig, 2007; Schor, 1991), subjective well-being (e.g., Juster et al., 1985; Linder, 1970), and consumer behaviours (e.g., Manrai & Manrai, 1995). Urban planning scholars are taking a time-geographic approach (Hägerstrand, 1970) to understand travel behaviours and transportation (e.g., Bhat & Koppelman, 1999). Interwoven in different disciplines, time use research attempts to help better understand the structural changes in the economy, society, and environment.

Embodying the three pillars of the same elements, economy, society, and environment, the discourse of sustainability has evolved into a transdisciplinary field over the past four decades. The definitions of “sustainability” or “sustainable development” vary slightly (e.g., World Commission on Environment and Development, 1987). Here, we borrowed the ecological economists’ understanding of “sustainability”: “a relationship between dynamic human economics systems and larger dynamics, but normally slower-changing ecological systems, in which 1) human life can continue indefinitely, 2) human activities can flourish, and 3) human cultures can develop; but in which effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system” (Costanza et al., 1991, p 8-9). This version of definition highlights the importance of promoting human well-being without degrading the natural capital. Time use, complimentary to monetary and biophysical data, is central to understanding the interaction across human social systems and ecosystems.

Indeed, the sustainability field has witnessed a growing interest in studying time use. Some topics in time use research can be directly linked to the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda for Sustainable Development. For example, the rising phenomenon of “time pressure” (studied by sociologists such as Staffan Burenstam Linder, Dale Southerton) has challenged the pursuit of Goal #3: good health and well-being. Struggling to maintain a healthy work-life balance, people are reported to have an increasing sense of “time stress”, and their leisure time has become rushed (Southerton, 2003; Southerton & Tomlinson, 2005). Beyond traditional economic accounts, social scientists have been utilizing time use data to measure the national well-being (Gershuny, 2011; Juster et al, 1985). Additionally, the unbalanced sexual division of unpaid labour might have stalled the progress towards Goal #5: gender equality. Most women bear the double burden of paid work and housework, which negatively affects both the quantity and quality of their leisure time (Mattingly & Bianch, 2003). Some linkages between sustainability and time use are understood in the context of lifestyles. For example, in order to measure the progress of transitioning to a lifestyle with lower environmental impacts, time-use data has been utilized to calculate the energy intensity of activities (e.g., Jalas, 2005), which indicates the energy demand related to different lifestyles. On a similar note, sustainability scholars have also become

curious about the environmental implications of the working time reduction policies (e.g., King & Van den Bergh, 2017; Shao & Rodríguez-Labajos, 2016). Their research in the intersection of work-life balance, well-being, and environmental impacts, attempts to predict what the future of work looks like and how people allocate their time then.

Time use research, enriched by decades of growth, is transcending the disciplinary silos. Despite the intuitive understanding of what constitutes the knowledge base and who are the contributing scholars, there has not been a study dedicated to delineating the boundaries within and documenting the disciplinary interconnectivity of time use research. As a result, this field remains as “a mosaic of specialities”, and scholars cite within their own communities, which may stall progress of data sharing and knowledge integration (Small & Griffith, 1974) To address these research gaps, this thesis project aims to gain a “bird’s eye view” of the time use research field and identify the major themes of its intellectual foundations. In particular, we are interested in how this field promotes the understanding of sustainability, in other words, how the sustainability theme emerges and interacts with the others. To achieve these goals, we combined the bibliometrics analysis approach, namely, document-level co-citation network and content-similarity network analyses, and qualitative scoping review.

1.2 Research questions

Using the combination of bibliometrics analysis and scoping review, this study is a preliminary attempt to answer the following three sets of research questions:

1A: How has the time use research field evolved over time?

1B: What are the most influential journals, authors, and documents in the field of time use research?

2: What are the dominant intellectual foundations in terms of disciplines and research themes in the field?

3A: What is the current state of sustainability topics in the time use field?

3B: How can time use research promote the understanding of sustainability?

The first set of two questions target the research front, the documents retrieved directly from the keyword search. The second is directed towards the intellectual foundations, derived from the co-citation data. The last set of two questions intend to focus on the sustainability community(ies) within the intellectual foundations.

1.3 Thesis structure

This thesis is organized as follows: Chapter 2 gives a brief literature review of the historical and recent development in time use literature, followed by an introduction of the bibliometric co-citation analysis to establish the methodology; Chapter 3 describes the methods this study used, including the field delineation, co-citation network analysis and its visualization, scoping review on the core sets of objects, manual testing for validity purpose, and the content-similarity network analysis; Chapter 4 presents and discusses the research front, intellectual foundations, and the major themes within the field. Chapter 5 develops a conceptual framework based on the results from the two network analyses and scoping review, followed by the limitations of this study and the recommendations for future research.

2. Literature review

2.1 A brief introduction of time use research

2.1.1 The historical development

Time use research can be traced back to the early 1900s when the original focus was almost exclusively on living conditions of the working class in the emerging industrial economy (Niemi, 1995; Harvey & Pentland, 1999). The former Soviet Union, the United Kingdom and the United States pioneered in conducting some time use studies before World War II (Niemi, 1995, 1999; Harvey & Pentland, 1999). For example, in 1924, Soviet economist Strumlin conducted time use studies for the purpose of governmental and communal planning. Meanwhile, in the U.S., a program focusing on household time use was launched at Cornell, and relevant studies have flourished since then (Harvey & Pentland, 1999). Historical time use research through the 1920s to 1950s was limited to regional and national levels. In the mid-1960s, the Multinational Comparative Time-Budget Research Project directed by Alexander Szalai (1972) established the first attempt to make cross-national comparisons. This project, which was conducted in 13 countries, contributed to the harmonization of subsequent national-level studies through formatting the survey methodology (Fleming & Spellerberg, 1999; Harvey & Pentland, 1999). Since then, national studies have been carried out on a regular basis by central statistical agencies in many countries including Japan, Canada, Korea, Norway etc. (Harvey & Pentland, 1999). Another landmark international effort has been made by the Multi-National Longitudinal Time Budget initiated by Jonathan Gershuny. This archive contains time use statistics of over 30 countries from the 1960s to the 1980s (Niemi, 1995), which is in the process of being reorganized and upgraded by Anne Gautier and Kimberly Fisher. The EUROSTAT project launched in the 1990s continues to promote the harmonization of time use surveys (Harvey & Pentland, 1999).

There are three components in the design of a time use study: survey design (i.e., the type of survey instrument used for recording activities and related aspects of design, the mode of data collection, and the type of household survey), sample design and selection, as well as activity classification (United Nations, 2005). Four

common approaches to measuring time use include “stylized” questionnaires, experience-sampling method (ESM), continuous observation, and time-use diaries (Gershuny, 2011). In a “stylized” questionnaire, respondents are asked to recall how much time they allocate to a certain activity over a specific period (United Nations, 2005). For example, they may be asked “how many hours per day (or per week) do you spend usually on *activity x*?” (United Nations, 2005). In the context of a 24-hour time diary, respondents report either their activities at certain time intervals throughout the day (full time diary), or “the time at which each activity occur based on an exhaustive list” (light time diary) (United Nations, 2005). Time diaries can describe “yesterday” or “tomorrow”, the latter of which is recommended by the Eurostat’s guidelines for its advantages in studying simultaneous activities and the contextual information (Eurostat, 2009). Some activities, such as child care, are normally done in parallel with the others. Therefore, an accurate account of simultaneous activities is important in certain types of time use studies (United Nations, 2005).

Time use data has wide applications in numerous fields of social sciences, including economics, sociology, anthropology, psychology etc. In the economics field, time use data supplements traditional economic measures by valuing unpaid work (household and volunteer). According to Bonke (1993 cited in Fleming & Spellerberg, 1999), domestic work (largely performed by women) should be given estimated values in national economic accounts to yield a complete picture of total production in the economy. Time use surveys can be used to recognize women’s economic contribution through domestic work, which is otherwise largely invisible.. The availability of time use data provides opportunities for more meaningful discussion on the sex division of labor. This part of research receives growing attention in gender studies. Another major application of time use data is the measurement of general well-being (“quality of life”) with the use of indicators such as leisure time. Douthitt (1984) first incorporated the time use perspective into measures of poverty. The linkage among time use, poverty, gender is further explored in development studies. Empirical evidence in developing countries (e.g. Ilahi, 2000) has shown that “households that rank poor on a consumption metric are also those where women have high work burdens” (p. 40). This expanded understanding of poverty was later coined as “time poverty” (Blackden & Woden, 2006). Time poverty or “time stress”

phenomenon might also be the case for industrialized developed countries when people with sufficient income feel they do not have enough time for leisure (Linder, 1970). To assess that, Hendrix (1986) developed a measurement of “harriedness” based on his longitudinal time use study of American societies. Time stress has become widely acknowledged in the well-being literature, which is also part of the sustainability research.

2.1.2 The integration of time use data in sustainability research

The adoption of a time use approach has been emerging in the sustainability field. Because of the sustainability triangle (social, environmental, and economic), time use (social), when linked to physical (energy and material use) and economic data, can generate some very interesting insights into the nature-society interaction (Smetschka, Gaube, & Lutz, 2016; Minx & Baiocchi, 2008). In light of the low-carbon economy transition, time-use data has been coupled with monetary and biophysical data in both consumption-based and metabolism-based approaches[1] to measure progress. To describe how time use research informs sustainability studies, anthropologist Daniel R. Gross (1984) states that “it measures the rates at which goods are produced… ; (it) can provide important data in studies of attitudes, values, cultural style, and emotions; any kind of behavior with an environmental effect can be observed using T(ime) A(llocation) techniques... ”(p. 519). In alignment with Gross (1984), Minx and Baiocchi (2008) agree that time use data is able to enhance the social and behavioural aspects of sustainability research. However, due to the differences in system boundaries for consumption-based and metabolism-based research, the adoption of time use approach looks different for the two sustainability clusters.

Originally developed as part of the Material and Energy Flow Analysis (MEFA) framework, time use data has been used by social ecologists and ecological economists for the analysis of social metabolism. Fischer-Kowalski et al. (2010)

[1] See Baynes & Wiedmann (2012) for a review on “General Approaches for Assessing Urban Environmental Sustainability”

pioneered in applying human time use patterns as one perspective, in addition to energy and material use, in the aim of comparing the social metabolism of four subsistence communities. The time use here is interpreted as a “limited but fairly evenly distribute resource” for system reproduction, which is distinctive from its traditional sociological sense (Fischer-Kowalski et al., 2010, p.6; Ringhofer, 2010). In the context of system reproduction, Ringhofer (2010) terms the approach as “Functional Time Use”. According to her description, human time use activities can fulfill the reproduction of the self (personal time activities, such as sleeping and eating), of household and family (housework, such as childcare and food preparation), of the community (voting, participation in cultural events, etc.), and finally, of the economy at large (labour work) (Ringhofer, 2010). This work is further expanded by Fischer-Kowalski and Haas (2016) in their theoretical article that discusses the role of human labour in the socioecological paradigm. Time use data is used to characterize human labour across different sociometabolic regimes, namely, the agrarian regime, the coal-based industrial regime, the oil-based industrial regime, and the continuing phase (Fischer-Kowalski & Haas, 2016). Of course, the Neolithic and the Industrial Revolution witnessed structural changes in terms of human time use. In Ringhofer, Singh, and Fischer-Kowalski (2014), they apply the theoretical framework treating human time as a limited biophysical resource, and compare the labour burden across gender and age of four subsistence communities. While revisiting Boserup’s (1965, 1981) theory of agricultural change, they are particularly interested in the gender differences in labour time, and acknowledge the “time poverty” experienced by women in some communities (Ringhofer et al., 2014). Similarly, in GenderGAP, a sustainable agriculture project for Austria, Smetschka et al. (2016) take a gender perspective and conclude the sustainable solutions for food production will not be realized unless the women farmers are freed from the higher work burden. This group of research also draw insights from land-time budget (LTB) analysis proposed by Pastore, Giampietro, and Ji (1999). Theoretically, the working time budget defined by the socioeconomic variables and the land availability constrained by biophysical resources, collectively dictate the food production activities and farming system development (Pastore et al., 1999).

Within the household consumption and consumer-lifestyle studies, time and physical inputs constitute the whole process of consumption. Wenke (1999 cited in Merz, 2002) endeavors to describe “sustainable consumption” within the household economic framework by combining time use and national account data. Similarly, Hofstetter and Madjar (2003) aim to link time use, happiness, and environmental impacts that are related to consumption activities. Notably, there has been a rising focus on household energy consumption or greenhouse gas (GHG) emissions with application of a time use approach in the fields of ecological economics and industrial ecology. The inclusion of time use data in this regard enables an activity-based approach towards depicting consumer-lifestyles, rather than solely depending on monetary expenditure (Minx & Baiocchi, 2008). Energy intensity of activities, indicated by the energy use per unit of time, is used to analyze structural changes of everyday life (Jalas, 2005; Wiedemhofer et al, 2018). Evident in Finnish data, people are increasingly engaging in low energy-intensive activities while the average energy intensities are still climbing (Jalas, 2005). In the British context, Druckman et al. (2012) find that leisure activities are in general less carbon intensive, and a higher percentage of men’s carbon footprint is contributed by leisure activities than women’s. On a similar note, Schor (2005, 2010) argue that the current lifestyles of overworking and overspending in the industrialized countries have stalled the progress towards a sustainable future. She suggests people to adopt a frugal mindset by shifting their focus from “quantity of stuff” to “quality of life”, and she advocates the working time reduction polices to be carried out in the industrialized countries (Schor, 2005). The emphasis on “work-life balance” has been emerging in the time use and well-being literature. Despite the obvious social benefits from a healthy work-life balance, there is little consensus about whether the reduction of labour time and its induced increase in leisure will for sure be beneficial to the environment. Stemming from the empirical findings, an interesting discussion on the “time use rebound effect” has also arisen. Jalas (2002) defines it as “the new activities a consumer engages in as a result of a less environmentally harmful product or service being substituted for an existing activity” (p. 118). It is shown that there are no significant correlations between working time and environmental pressure for the developing countries, and the correlations are not always positive in the context of developed countries (Shao & Rodríguez-Labajos, 2016). They indicate

the rebound effect might due to the participation in some carbon-intensive leisure activities (Shao & Rodríguez-Labajos, 2016).

In summary, the sustainability discourse has recognized the descriptive and quantitative value embedded in time use data. Despite the increasing adoption of time use perspective in socio-metabolic and household consumption studies, there has not been a comprehensive review on the current state of the sustainability time-use research, nor do the above-mentioned two sustainability clusters acknowledge each other's work too often through citation.

2.1.3 Research gaps

There are a lot of other fields approaching the topic of time use, some of which, as listed above (e.g. gender, development, sustainability studies), are highly inter- and multi-disciplinary. However, the comprehensiveness of time use research has not been well-documented. Despite efforts made by Pentland, Harvey, Lawton, and McColl (1999) in their book *Time Use Research in the Social Sciences*, which introduces the historical development of time use research and showcases some projects from different fields, there is a lack of work on modeling the dynamics of research fields as they are in fact interconnected. Such comprehensive mapping work if done properly can help understand the structure of the entire time use research academic community through visualizing "how disciplines, fields, specialties, and individual articles or authors are related to one another" (Small, 1999, p. 799). More importantly, it will help identify future research opportunities. Also, in regards to time use applications in sustainability studies, which we have particular interests in, there is no comprehensive review to synthesize the relevant work.

In this study, we intend to bridge the gaps by mapping the field of time use research though bibliometric analysis, namely the co-citation network and content-similarity network analysis. The below section reviews the methodological grounds of this thesis.

2.2 Bibliometrics and science mapping

2.2.1 Overview: origins, scope, and applications

This section provides some background information on bibliometrics, including its origin, definitions, scope, and applications with a special focus on science mapping. The word “bibliometrics” is formed by two roots: “biblio” and “metrics”, the former of which refers to “book”, and the latter is “measurement” (Sengupta, 1992). As the word roots suggest, the term simply means the “measurement of books (documents)”. The coinage of this term is widely attributed to Pritchard (1969) despite the fact that the concept (described as “statistical bibliography”) was already present in the 1890s (Sengupta, 1992). Pritchard (1969) defined it as “the application of mathematics and statistical methods to books and other media of communication” (p. 349). Hertzel (1985, p. 43) gave a more explicit definition for “bibliometrics”: “the science of recorded discourse -- which uses specific methodologies, mathematical and scientific, in its research in a controlled study of communication. It is the body of literature, a bibliography quantitatively or numerically or statistically analysed -- a statistical bibliography, a bibliography in which measurements are used to document and explain the regularity of communication phenomena”.

Bibliometrics is generally divided into two categories: descriptive and evaluative (Potter, 1988; Stevens, 1953). Descriptive bibliometrics, according to Stevens (1953), aims to compare the amount of research in different geographic locations, and/or during different time periods, and/or in different disciplines by counting the number of publications or productivity of literature. Evaluative bibliometrics, or sometimes described as the literature usage count, attempts to study the relationships between literature components through citation analysis (Potter, 1988; Stevens, 1953). Citation analysis is a distinctive and widely-adopted approach, the discussion and application of which constitute the most fruitful research subfield of bibliometric studies. There are varieties of citation analyses according to a number of classification rules. Based on different measure techniques of the interrelationships between citing and cited objects, there are co-citation analysis built upon co-citation counts (Small, 1973; White & Griffith, 1981), bibliographic coupling analysis upon bibliographic coupling frequencies (Kessler, 1963), etc. With different scopes of

interests, there are citation network analysis and evaluative citation analysis, the former of which is widely adopted to map research fields and study their intellectual structures (Zhao & Strotmann, 2015). Co-citation network analysis is the main approach of this paper and will be discussed in details in Section 2.2.2.

Despite some consensus in favor of dividing bibliometrics into two camps, Hertzel (1987) indicates that this categorization seems reductive. He argues that evaluative bibliometrics is constructed from top-down descriptions (Hertzel, 1987, p. 156 cited in Osareh, 1996). For example, although citation analysis is understood as a major part of the evaluative bibliometrics, the evaluations (not specific to evaluative citation analysis) cannot stand alone without statistical descriptions of the studied objects as a whole. Similarly, Nicholas and Ritchie (1978, p. 11) believe that the descriptive and evaluative (they termed as "behavioural") aspects of bibliometrics are complementary to each other (cited in Osareh, 1996). As Pritchard (1969) points out, the ultimate purpose of bibliometrics is "to shed light on the process of written communication and of the nature and course of development of a discipline (in so far as this is displayed through written communication), by means of counting and analysing the various facets of written communication" (p. 348). The wide scope of bibliometrics allows its various applications in scientific fields.

Bibliometrics itself originates in the field of Library and Information Science (LIS), documented and popularized by journals such as *Information Sciences*, *Journal of Informetrics*, and *Scientometics*. Meanwhile, it has gained currency in many other disciplines in both social and physical sciences (Sengupta, 1992). Main applications of bibliometrics include 1) measuring "productivity" and quantifying "impacts" of publications; 2) mapping the structures of knowledge, tracing the diffusion of ideas, and forecasting trends (Osareh, 1996, p. 152; Sengupta, 1992, p. 82). The first kind, largely relied on evaluative citation analysis operationalized by bibliometric indicators, such as impact factor, *h*-index, etc. The underlying assumption is that higher citation rates correspond to higher "impacts" (Zhao & Strotmann, 2015). Although there are some criticizes, this type of bibliometric application is widely adopted by authors, journals, institutions, etc., to measure and compare their "productivity" and "impacts".

Science mapping, the second type, is what we have conducted for the time use research field. To comprehend the rationale behind science mapping, we first need to understand what science is constituted of. Small and Griffith (1974) describe science as “a mosaic of specialities” (p. 17). Speciality, the building block of science, according to Morris and Van der Veer Martens (2008), is “a self-organized network of researchers who tend to study the same research topics, attend the same conferences, read and cite each other’s research papers and publish in the same journals” (p. 214-215). It is not only a real social network of collaborative researchers, but also a virtual network of both shared knowledge base and research topic interests (Morris & Van der Veer Martens, 2008). Within this cluster, researchers build their studies upon each other’s by sharing concepts, methods, and findings (Culnan, 1986). “The history of exchanges between members of these subgroups in a discipline describes the intellectual history of this field” (Culnan, 1986, p.156). Science evolves as changes happening in research specialities. To facilitate the creation of new knowledge, we require the retrieval of old knowledge and trace of knowledge diffusion within and across these specialities. However, as Small and Griffith (1974) point out, there has been a lack of “bird’s-eye view” of the “scientific mosaic”. In other words, the intellectual structure of science, or any scientific field, still remains invisible to outsiders (e.g., funding agencies, policymakers, researchers from other specialities/ fields, etc.) and even insiders (i.e., researchers of one speciality in the field) if no “mapping” work done beforehand.

The map of science is a spatial representation of the structure and interconnections of authors, published documents, etc., within or across specialities (Morris & Van der Veer Martens, 2008; Small, 1999). Therefore, science mapping is a process of analyzing and visualizing the intellectual structure and dynamics of an interested field (Chen, 2017). In this section, we used the term “science mapping” to exclusively refer to the type that applies bibliometrics. In the context of descriptive and evaluative bibliometrics, it falls into the category of descriptive bibliometrics even though citation analysis is largely utilized to describe the interconnections (Morris & Van der Veer Martens, 2008). Co-citation (Small, 1973; White & Griffith, 1981) and co-word analyses (Callon, Courtial, Turner, & Bauin, 1983) are two common bibliographical approaches of science mapping (Cobo, López-Herrera, Herrera-Viedma, & Herrera, 2011; Morris & Van der Veer Martens, 2008; Small, 2006). Co-

citation analysis at the document level (Small, 1973) is the main approach for us to study the intellectual structure and dynamics of the time use field. Because the map resembles a network, network visualization tools are also applied for the purposes of this study (see Section 2.2.2. for co-citation analysis).

Before discussing the benefits and limitations of science mapping, we want to take a step back and look at the other two methodologies of conducting a literature review, which are meta-analysis and descriptive literature review. Meta-analysis is an approach of quantitatively synthesizing the significant relationships among variables from various sample studies (i.e., no case studies or theoretical studies) that meet researchers' inclusion criteria and aggregating them into one finding (Copper, 2003; Raghuram, Tuertscher, & Garud, 2010). In the context of time use research, meta-analysis is a great way to explore the relationships among time use and other variables because of the cross-utilization of the same time use survey. For example, in a recent study published in the Journal of Positive Psychology, the researchers conducted a meta-analysis of 12 articles on the strength of effects between leisure time, physical activity and subjective well-being (Wiese, Kuykendall, & Tay, 2018). Within the economics cluster, Hamermesh (2016) outlines a series of questions that prompt meta-analyses on the topics of time allocation, the value of time, household division of work and their effects on economic activities. Compared to science mapping, meta-analysis has the same quantitative rigour while it usually has a smaller scale of inclusion and focuses only on empirical findings. Descriptive literature review, including scoping review, on the other hand, is conducted with researchers carefully reading and summarizing a set of studies (can include case and theoretical studies) under certain frameworks (Raghuram et al., 2010). For example, in a literature review on children's daily activities and well-being, the researchers identified specific gaps in the literature by reviewing 22 children's time use studies (Ben-Arieh & Ofir, 2002). Unlike science mapping, which has the capacity to deal with a large quantity of literature, descriptive literature review requires an intense workload from researchers, and therefore, has a much smaller scale. However, it rewards with a more in-depth analysis. In other words, descriptive literature review takes a micro-perspective and pays attention to contextual information while science mapping aims for a macro-perspective. Also, in contrast to science mapping, which has a quantitative rigour with its statistical and mathematical

base, descriptive literature review or scoping review is based on researchers' subjective insights.

It becomes obvious that science mapping with bibliometric techniques is a great way to visualize the intellectual structure of any scientific field, especially an inter- and multi-disciplinary field such as time use, which is otherwise difficult to discover the specialities within. In this way, it becomes easy to track knowledge diffusion, facilitate knowledge integration, and ultimately, build "consilience" across clusters within a field (Small, 1999; Trujillo & Long, 2018). However, science mapping or any other applications of bibliometrics, is limited to its quantitative characteristic. De Bellis (2009) describes the limitations in simple words: "Numbers alone do not suffice to tell the whole story about science, nor do they necessarily tell a true one". First, pertaining to science mapping, it is only able to provide a snapshot of the field based on certain similarity assumptions. For example, if co-citation relationship is used to map the field, the final product will be based on the assumption that the more frequently two articles are co-cited, the more closely they are related in subjects or methods (Borgman, 1990; White, 1990). It is a valid method in general, but meanwhile, we do not have much information about the context in which they are co-cited. Second, numbers do not always translate to "influence". This is the case when we are trying to identify prominent authors based on citation counts. Do more citation counts always mean more "influence", let alone different citation behaviours across disciplines and the complexity behind citation counts of multi-authorship works? Despite these limitations, bibliometrics still provides powerful toolkits to complement qualitative analysis. Depending on the units and scales of analysis, the target audience of bibliometric analysis ranges from funding agencies, institutions, to researchers, either established or newcomers to the field.

In conclusion, recent decades have witnessed the growing popularity of bibliometric applications in enormous fields. It continues to gain currency with the increasing accessibility of bibliometric datasets and the availability of visualization tools.

2.2.2 Database, software, and co-citation

In this subsection, we compared two main bibliometrics databases, Scopus and Web of Science (WoS); briefly reviewed several analytical and visualization software on the market; and explained the rationale and limitations behind co-citation.

2.2.2.1 Web of Science vs. Scopus

Bibliometrics analysis is made possible by the intensive archiving and indexing work behind citation database construction. WoS core collection and Scopus are two commonly used databases for all disciplines (Zhao & Strotmann, 2015). The criteria selected to compare the two are coverage, indexes, and download options. Normally, bibliometrics analysis favors citation databases that have a wider coverage, a somewhat rigorous selection, and a stable coverage growth over time if it is for a longitudinal study (Zhao & Strotmann, 2015). In total, Scopus surpasses WoS core collection in the coverage of journals, which can be partially explained by a larger exclusive journal collection they have (IOWA State University Library, 2019; Mongeon & Paul-Hus, 2016; Web of Science; 2019; Zhao & Strotmann, 2015). According to the modified comparisons done by the IOWA State University Library (2019), Scopus is reported to have stronger interdisciplinary coverage. For both, the coverage of Social Sciences and Humanities is far from exhaustive compared to Natural Sciences, Health Sciences, and Engineering (Moed, 2010; Mongeon & Paul-Hus, 2016). In a comparative analysis on the two databases' journal coverage in 2016, Scopus has a coverage of approximately 25% of the Social Sciences and Humanities fields; WoS, less than 15% (Mongeon & Paul-Hus, 2016). However, WoS core collection has an advantage on the rigour of journal selection and stability of indexing. Part of the reason is, Scopus, which was launched in 2004, is younger and still reprocessing and enriching its records, especially the cited references (Zhao & Strotmann, 2015). In terms of indexing, the major differences between the two are on the cited references, which is the main component for the co-citation analysis. Scopus has a quite complete profile for the cited references in their downloaded

records while WoS core collection is missing on the titles, journal names, and authors beyond the first one, which might result in accuracy concerns and interpretation difficulties for citation analysis (Zhao & Strotmann, 2015). In addition, for bibliometric analysis that requires a larger dataset, Scopus only allows free downloads for the first 2000 records. In contrast, WoS enables manual downloads of 500 records at a time. We summarized the main advantages and disadvantages of each in terms of coverage, indexes, and download options in the Table 1 below:

Table 1

Scopus vs. Web of Science

	Scopus	WoS Core Collection
Coverage	Slightly larger coverage in Social Sciences and Humanities Strong interdisciplinary field coverage Wider and less selective, but unstable coverage and indexing	Weak interdisciplinary field coverage More stable coverage over time than scopus
Indexes	Quite complete, including full title, name of the journal, names of the first seven authors and of the last author	The titles of cited references, full journal names, and other authors' names (only first author) are not indexed
Download options	Only the first 2000 can be downloaded	500 downloads at a time

2.2.2.2 Network analysis and visualization software

To process the downloaded bibliographic data, mostly in an excel compatible format, there is quite a few of analytical and visualization software available. We compiled a list of five network analysis and/or visualization software in Table 2. Most of the software on the market are free to download and open-sourced. Among the social

network analytical tools, CiteSpace, in contrast to Bibexcel and *Metaknowledge*, is designed to be the most compatible to WoS databases (Chen, 2006). *Metaknowledge*, however, has the advantage of supporting raw data from more data sources such as Proquest Dissertations and Theses (McLevey & McIlroy-Young, 2017). For Gephi and Pajek that are popular for their visualization capabilities, raw data downloaded from citation databases usually needs to be reprocessed and optimized through network analytical software such as the three mentioned above, although Gephi does support CSV formatted data for its network analysis, such as centrality measures (Bastian, Heymann, & Jacomy, 2009; Mrvar & Batagelj, 2016).

Table 2

Comparisons among five network analysis and/or visualization software

	Accessibility	Compatible input database(s)	Applications
Bibexcel[2]	Free	WoS, Scopus...	Various citation analysis; Preparing bibliometric maps for visualization...
CiteSpace[3]	Free, Java-based	WoS (primarily)	Network analysis; Knowledge domain visualization...
Metaknowledge[4]	Free, Python-based, open source	WoS, Scopus, PubMed, ProQuest Dissertations & Theses...	Network analysis; Computational text analysis...

[2] Persson, O. (2009). How to use Bibexcel for various types of bibliometric analysis. *Celebrating Scholarly Communication Studies*, 9–24.

[3] Chen, C. (2006). Citespace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. Journal of the Association for Information Science and Technology, 57(3), 359–377.

[4] McLevey, J., & McIlroy-Young, R. (2017). Introducing metaknowledge: Software for computational research in information science, network analysis, and science of science. *Journal of Informetrics*, *11*(1), 176–197. https://doi.org/10.1016/j.joi.2016.12.005

Gephi[5]	Free, open source	Databases that support CSV; Graph file formats	Network analysis and visualization
Pajek[6]	Free, Python-based, open source	Raw data from citation databases needs to be reprocessed to network compatible formats, such as UCINET DL	Network analysis and visualization

2.2.2.3 Co-citation analysis

Citation analysis, one of the most common approaches in bibliometrics, has been popularized by the field of information science, and gradually introduced to other disciplines (Snyder, Cronin, & Davenport, 1995). To clarify the usage of "citation" and "reference" sometimes confused by people outside the field, Zhao and Strotmann (2015) explain it that "a reference from article A to article B is a citation received by B from A" (p. 2). Here, article A is the citing article, B is the cited article. There are many intentions behind citations, Garfield (1979) summarizes fifteen reasons, some of which are "paying homage to pioneers, giving credits for related work, and criticizing previous work…" (cited in Smith, 1978). Similarly, Leydesdorff (1998) agrees that there is no consensus in interpreting citation behaviours without contextual information. However, regardless of the behavioural factors, cited documents are treated as "concept symbols" that "may be freely combined and juxtaposed, unhampered by the customary rules of logic or syntax, to suggest by analogy a wide range of conceptual possibilities" (Small, 1981). In alignment with this thinking, it suggests that citation analysis can be leveraged to map the structure of science (Small, 1999) and identify "invisible colleges" (Price, 1965). In particular, Small (1973&1999) proposes and endorses the use of co-citation patterns.

5 Bastian M., Heymann S., Jacomy M. (2009). Gephi: an open source software for exploring and manipulating networks. International AAAI Conference on Weblogs and Social Media.

6 Mrvar, A., & Batagelj, V. (2016). Analysis and visualization of large networks with program package Pajek. Complex Adaptive Systems Modeling, 4(1), 6. https://doi.org/10.1186/s40294-016-0017-8

Co-citation is a form of citation relationship that links cited documents (also known as knowledge base). Document-level Co-citation Analysis (DCA), one of the variations of co-citation analysis, measures the frequency of documents being cited together by later literature (Small, 1973). Unlike bibliographic coupling (Kessler, 1963), co-citation focuses on cited documents rather than citing documents (research front). Figure 1 describes how the two differ in their measures.

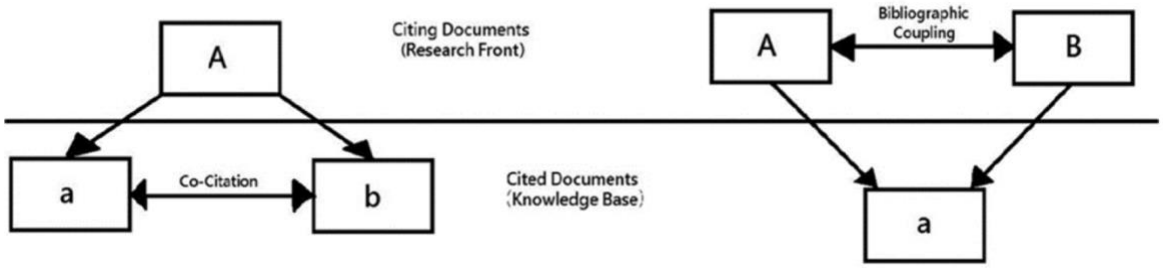

Figure 1. Comparison of mapping procedures

Note. Reprinted from Strength in small: the University of Malta's scientific output since accession, McMillan, G. S., St-Louis Lalonde, B., Bezzina, F. H., & Casey, D. L. (2016). *International Journal of Innovation Science*, *8*(3), 269–287.

Co-citation analysis is commonly used to understand the foundational work (i.e. knowledge base) of a field because of its focus on the cited documents (Small, 1973; Vogel & Güttel, 2013). The frequency of the two documents being co-cited is reflected on the co-citation strength; higher strength indicates higher subject similarity as well as association or co-occurrence of ideas (Small, 1973). A tightly-knitted collection of co-cited documents can be interpreted as a "community", and adjusting the edge weight threshold can either merge or fragment the "communit(ies)" (Trujillo & Long, 2018). Considering it a social network, different centrality measures can be applied. For example, betweenness centrality measures the frequency of a node (co-cited document in this case) being located on the shortest path between the others in the network (Leydesdorff, 2007). If deleted, a node with a high level of betweenness centrality will lead to the collapse of a network; hence, the document itself is usually interpreted as highly inter- and multi-disciplinary (Leydesdorff, 2007).

Despite the wide application of co-citation network analysis, the limitations have been acknowledged, as well. First, it suffers from its quantitative nature. In other words, the intentions behind the citation are unclear without the contextual information (Garfield, 1979; Leydesdorff, 1998). Therefore, it is oversimplified to reduce it to mere citation counts and treat all citations the same (Small, 1978; Smith, 1981)[7].On the same note, the lack of knowledge of how the documents being cited, for example, if the citing document are referencing similar contents of the two cited work, challenges the basic consumption of co-citation being translated to content-similarity (Smith, 1981). In addition, citation behaviours vary in different fields, which ultimately affect the citation and co-citation counts (Smith, 1981). The uncertainty remains when using co-citation counts to map an inter-disciplinary field.

Second, It is worth noting that co-citation is a dynamic measure because of its reliance on the accumulation of citations over time through the acts of the citing documents, in comparison to the strength of bibliographic coupling being static (Small, 1973; Vogel & Güttel, 2013). For this reason, it is critical for the timing of co-citation analysis. A recent published article may not have enough citations, let alone co-citations. However, with the passing of time, it has the possibility to become a highly co-cited document. To some degree, it poses challenges in recognizing such work with a “snapshot”-like analysis (Trujillo & Long, 2018). Having already recognized this limitation, Small (1973) suggests using co-citation to study the growth of a field.

Finally, co-citation analysis, similar to the other types of citation analysis, is constrained by the quality of the input data. As simply put by Smith (1981), “citation analysis…, can be no more accurate than the raw material used” (p. 93). On the one hand, the indexing errors are inevitable in citation databases. On the other hand, the search terms might not retrieve the intended data as they are supposed to do (Trujillo & Long, 2018).

7 Issues surrounding self-citations have been heavily discussed.

For the limitations above, researchers have been warned to proceed with caution when it comes to citations, and it is better if citation analysis can be triangulated with other approaches (Snyder, Cronin, & Davenport, 1995). We briefly mentioned literature review or scoping review being one qualitative method to provide in-depth contextual information underlying the co-citation network. Additionally, we redirected our attention from the reference lists to the abstracts, and explored mapping the field with the method we termed as “content-similarity network analysis”, which is based on the measures of the cosine similarity. The below chapter details how we conducted the data collection and analysis step by step.

3. Method

Co-citation network analysis and scoping review, the two complementary methods, were combined in our study. To start, the first step was to delineate the field of time use research by collecting a fairly clean and complete set of data (Section 3.1). The second was the co-citation network analysis and visualization via the Python software *metaknowledge* and visualization tool Gephi (Section 3.2). To contextualize the quantitative results, we conducted a scoping review on the 10 largest communities detected from the co-citation network (Section 3.3). With the knowledge of the thematic construct of the field, we were able to determine if the map was representative to the academic world reality or not. If there were discrepancies, I proceeded to a bottom-up testing using the manually extracted lists of references (Section 3.4). In this case, to triangulate the co-citation network analysis method, we extracted the abstracts of their referred time use articles and constructed a network based on the content similarity (Section 3.5). The results were interpreted further and presented in the discussion chapter (Chapter 5.0). The interpretation helped re-delineate the undefined time use research field. This chapter is organized according to the 5-step flowchart (See *Fig. 2*).

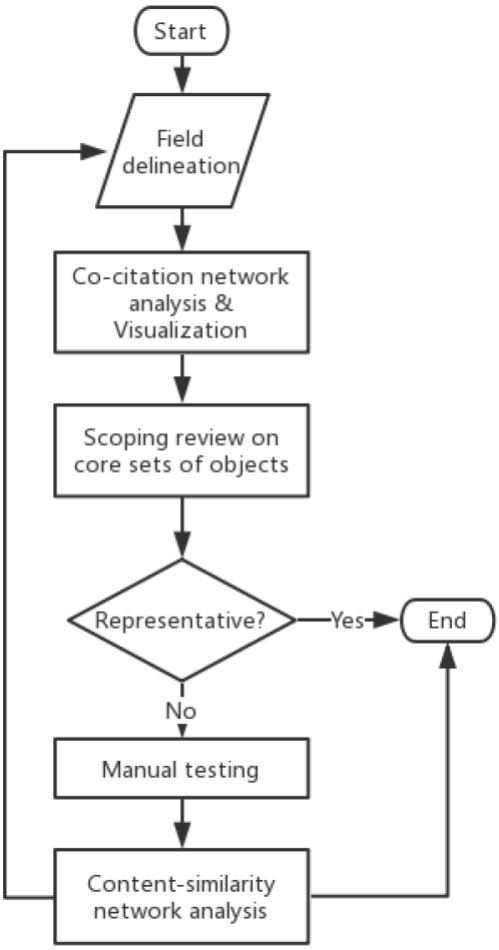

Figure 2. Five-step process for mapping and scoping the time use research field

3.1 Field delineation

The first step of a citation analysis is to retrieve a set of citing documents that are representative of the studied research field (Zhao & Strotmann, 2015). These citing documents constitute a “research front” (Price, 1965), and what they have cited (found in their reference lists) reveal the intellectual base of the field. However, to understand the structure and characteristics of a multi- and inter-disciplinary research field, such as time use research, a robust “field delineation” approach is often required. In section 3.1.1, we explained the search strategies used in this study, including the choices of dataset and keywords. In section 3.1.2, we described

the data refinement steps. After obtaining a clean and complete dataset, I elaborated on how we used *metaknowledge* for analyzing the research front, in section 3.1.3.

3.1.1 Search strategies

Time use research is a highly multi- and inter-disciplinary field with no well-defined definitions. Therefore, it is challenging to find precise search terms that are representative of this field. The keywords I used for data collection were “time use” and “time diary”, both of which retrieved time use studies with “time use survey” or “time diar(ies)” identified as their research methods, and the former could also return articles pertaining time perception. In addition to the articles from the keyword search, we also included those published in the core journals of time use research. Two peer-reviewed journals were pre-defined as the core: *Time & Society* (ISSN: 0961-463X) and *the electronic International Journal of Time Use Research (eIJTUR)* (ISSN: 1860-9937). Both journals are dedicated to present research across a range of disciplines, with theoretical, methodological, and empirical focuses on individual and societal time-use. Scopus database was chosen to perform such data collection in because 1) it has a wider coverage of journals compared to ISI databases 2) *eIJTUR* is only indexed in Scopus not ISI databases.

To retrieve the articles from the two core journals, we used the query string: *SOURCE-ID (18718) OR SOURCE-ID (21100229114)* in Scopus advanced search. In Scopus database, the two ID numbers refer to *Time & Society* and *eIJTUR*, respectively. To collect the time use studies scattering in other journals, we used the keywords mentioned above in the “article title, abstract, keywords” field. The search string *TITLE-ABS-KEY ("time use" OR "time diar*")* returned 5879 records on February 27, 2018. With the assistance from Elsevier’s research management team, we were able to retrieve all records beyond the 2000 download limits of Scopus. After a quick scan, we found the initial search caught a large percentage of documents irrelevant to our focus. The keyword “time use” appeared in common phrases, such as “first time use”, “long time use”, “real time use”. Also, the search term was sometimes interrupted by punctuations, for example, “time, use”, “time. Use”, “time: diary”. Documents returned in the above two cases were normally not time use studies, therefore, categorized as “noise” in the data collection. The next section explains the steps for data screening and cleaning.

3.1.2 Data refinement

As indicated above, the data consists of two parts: articles that are indexed in Scopus from *Time & Society* and *eIJTUR*; articles returned by keyword search in Scopus. To obtain a complete and clean dataset, the second part of data requires further refinement. We used the initial search on February 27, 2018 as a trial to get an idea of how "noise" was captured. Firstly, we sorted the 5879 results in ascending order (A-Z) of the first authors. Secondly, we manually screened the first 500 records (around 8.5% of the total). Because the results were sorted in an alphabetical order of author names, the first 500 records were a fair representation of the pool. After carefully reading the abstracts, we excluded 190 documents out of the 500. The title, exclusion reason, and triggered keyword were documented for each. Based on the list, we generated a frequency table (see *Appendix A*) of these keywords (9 random cases could not be categorized to any). A large portion of the documents irrelevant to the study came from keywords interrupted by punctuations (e.g. "time, use", "time. Use"). Then, it was followed by other common phrases that incorporated "time use" (e.g. "first time use", "real time use"). Rare cases (6/500) were documents that focused on the time use perspective of other species. I took notes of these documents' source titles, which were mostly biology journals (see "Additional notes" row of *Appendix A*). If the "noisy" keywords were only a handful and in simple forms, it would be ideal to eliminate the irrelevant documents by including these keywords in the Scopus search query after the "AND NOT" operator. However, in this study, there were 15 unique ones along with their variations. Also, it was noted that punctuations cannot be used in search terms, which made it difficult to get rid of the most frequent ineligible returns. Because the downloads from Scopus were in CSV format (easily displayed in Excel), we utilized the "conditional formatting" function in excel for the data-cleaning process.

On March 8, 2018, we retrieved the most current dataset to that date using the query string: *TITLE-ABS-KEY ("time use" OR "time diary") OR SOURCE-ID (18718) OR SOURCE-ID (21100229114)*. We discarded the wildcard because we found in the trial that "time diar*" triggered "diarrhea" by mistake, and the singular noun by itself

would return the plural in Scopus, as desired. The combination of the two parts of sources retrieved 6374 records. The search *TITLE-ABS-KEY ("time use" OR "time diary")* alone yielded 5870 returns; *SOURCE-ID (18718) OR SOURCE-ID (21100229114)* alone, 572 returns. Limiting the search to only “journal” articles (conference papers, reviews, book chapters etc. excluded) in English, we found 4498 records remaining. For further refinement, we exported the 4498 records into a CSV file and opened it in Excel (2016 version). In the Excel worksheet, titles, abstracts, keywords, cited references, as well as other citation and bibliographical information, were categorized in corresponding columns. We went to “Conditional Formatting > Highlight Cells Rules > Text that Contains” and then entered the keywords that triggered the “noise” as they appeared in the frequency table, one by one. The rule generated in this way looked like: Cell Value contains “*keywords*”. Neither Excel “Cell Value contains” nor Scopus keyword search were case-sensitive. However, it was worth noting that the “Cell Value contains” in Excel, unlike Scopus search term rule, only returned records “containing” keywords in the identical form. For example, the search “time use” triggered both “times use” and “time uses” in Scopus, but not the former in Excel. Similarly, “first-time use” would not return “first-time-use”, but only its original form and “first-time uses” in Excel. Therefore, to fully utilize the conditional formatting feature for the purpose of data-cleaning, I also did extensional search in Excel using keywords with hyphens added or removed (See “Extensional search term” column in *Appendix A*).

With the application of the rules to the columns of titles, abstracts, and keywords in Excel, 1443 records were highlighted in the worksheet. After a scrutiny of each record, 1427 were excluded from the collection with reasons. Then, we filtered out the source titles in the notes from the corresponding column, including 6 journals identified in the trial and 2 new ones (i.e. Zoo Biology and Experimental Animals) found during the filtering process. This step of screening out the studies on other species led to 8 exclusions of articles in total. As a result, 3063 articles remained eligible for co-citation analysis (See *Fig. 3*).

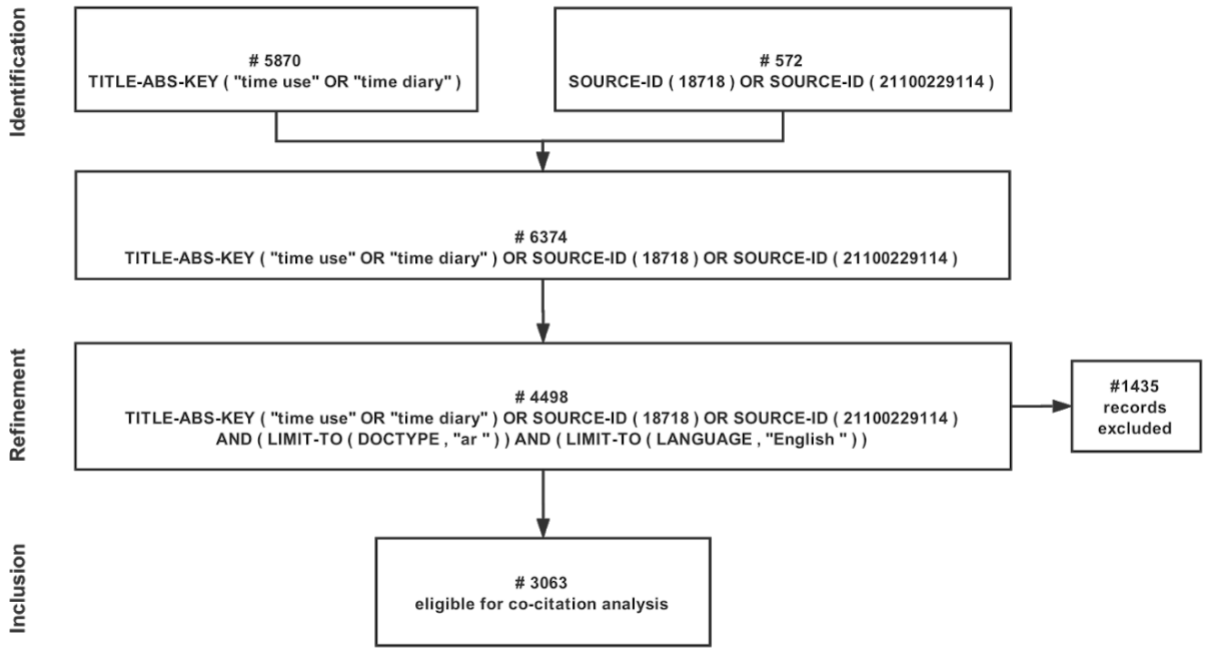

Figure 3. Phases of data retrieval

Note. Future researchers can put "AND ORIG-LOAD-DATE > 20180308" at the end of the final query string to retrieve data added by Scopus after our data retrieval deadline (March 8, 2018), and create a search alert if needed.

3.1.3 Research front analysis with *metaknowledge*

As briefly mentioned in the literature review chapter, *metaknowledge* is a Python 3 package for network analysis (McLevey & McIlroy-Young, 2017). This software was utilized for analyzing the research front as well as the document-level co-citation network. We wrote our Python scripts (see *Appendix B*) in a Jupyter Notebook, which can be run easily in a web browser.

First, we imported the package with these few lines in the first code cell. Then, we loaded the directory of our cleaned Scopus data into *metaknowledge*, created a "RecordCollection" and named it "RC", which would be the main object we interacted with later. This command cached our 3063 records, as expected. The growth of the

3063 articles that constituted the research front can be overviewed by creating a time series dataset and saving it as a CSV file. A time series plot was created in Excel using the data. Also, we were interested in the authors, journals, and articles with the highest frequencies in the collection. Therefore, we used the “glimpse ()” method to get a quick snapshot of the RC. Unfortunately, information on subject areas and CiteScore[8] was not included in the RC, but was easily obtained in the journal and author profile pages in Scopus.

With these lines of a script, we analyzed our 3063 articles as themselves to understand how the time use research field has evolved over time; and what the most influential journals, authors, and documents are in the field of time use research. In the next section, we continued to use *metaknowledge* for co-citation network analysis on the cited references of these articles.

3.2 Co-citation network analysis & visualization

3.2.1 Co-citation network analysis with *metaknowledge*

As explicitly explained in the literature review chapter, co-citation network analysis is one type of bibliometric analysis. Co-citation frequency measures how often two documents are cited together (Small, 1973). Co-citation networks can be generated for a field by extracting the lists of references and counting the co-citation frequencies. To better understand the knowledge base of the field of time use research, we combined Document-level Co-citation Analysis (DCA) and network analysis with the application of *metaknowledge.* We explained the steps in text here, and attached the full script in *Appendix B*.

We used the co-citation network generator to create the network with the citations[9] extracted from the “Records” of our “RecordCollection (RC)”. Each citation record is

[8] Scopus unique metric on measuring average citations received per document published in the serial. The implications of CiteScore are similar to impact factors.

[9] The citation collection included all types of documents, not limited to journal articles.

identified with their first author, year, and source title. By default *metaknowledge* creates a co-citation network that includes all items in the cited reference lists. However, there are two ways to apply thresholds. First, *metaknowledge* allows us to create a network that only includes items core to the RC, using the optional argument “coreOnly = True”. It means those documents *not* published in journals already existed in the records will not show up as nodes in the network. To make our network more inclusive, we kept the argument *false*.

Second, *metaknowledge* enables researchers to drop nodes based on edge weight thresholds, degree thresholds, etc. We considered weight under 3 as noise, dropped the self-loops, but kept the edge degree as 1 to make the network more inclusive.

After the network being created, we used a modularity-based community detection algorithm, the Louvain method (Blondel, Guillaume, Lambiotte, & Lefebvre, 2008), which is implemented in *community* package, to partition the network into communities. A community is a cluster of densely interconnected nodes. When modularity is optimized, a network will be decomposed into certain numbers of communities.

We used degree, eigenvector, and betweenness centralities to measure our co-citation network. We computed these centrality scores, put them in a dataframe with one added column for community memberships, and created a scatterplot matrix for eigenvector and betweenness centralities.

3.2.2 Visualization with Gephi

The network can be visualized in a two-dimensional map. We assigned graph attributes and attached article titles to the nodes (can do so if the titles were included in the RC themselves).

In our case, it was challenging to visualize the graph in details. Alternatively, we wrote it to a graphml file that can be read in visualization softwares such as Gephi.

In Gephi, we kept the graph type as default (undirected) when opening the graphml file. On the “Statistics” panel, we ran the “Modularity” algorithm, the Louvain method implemented in Gephi. The modularity settings were kept default[10] as well. This step created a “Modularity Class” value for each node. Then, we colourized the communities via the partition module using the newly-attached values. To improve the readability, the co-citation network was then mapped using the “ForceAtlas 2” layout algorithm, which claimed useful for a rigorous data interpretation with the fewest biases compared to others (Gephi, n.d.).

After obtaining the co-citation network, our next step was to generate a narrative for the major communities (clusters) and most importantly, the sustainability communit(ies), if there were any, by performing a scoping review. This process aimed to complement the quantitative nature of the bibliometric analysis.

3.3 Scoping review

Scoping review, one of the variations of descriptive literature review, is a technique that “aim(s) to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as stand-alone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before” (Mays et al., 2001, p. 194). Arksey and O’Malley (2005) argue that this definition does not clarify the varying degrees of “depth” achieved in different kinds of scoping reviews. They list four types of scoping review, two of which are 1) “to examine the extent, range and nature of research activities; 2) to identify research gaps in the existing literature” (Arksey & O’Malley, 2005, p. 5-7). The first can be the preliminary stage of a full systematic review while the second can stand by itself because of the potential contribution to a “deeper”

[10] Randomize: On; Use edge weights: On; Resolution: 1.0

understanding of the field (Arksey & O'Malley, 2005). The purpose of scoping was two-fold in this paper as well. First, I aimed to delineate the field of time use research by examining the nature of the communities detected via the co-citation network analysis; second, I planned to "zoom in" on the sustainability communit(ies)[11], which our "invisible college" is identified as, and found the research gaps in the existing literature of this (or these) communities.

One of our research questions was: what are the dominant intellectual foundations in terms of disciplines and research themes in the field? I aimed to answer this question through the first type of scoping review on the top 10 largest communities, which had above 50 members (documents) in each and covered 70.8% (2270 documents) of the entire collection. Considering the large quantity, it was infeasible for me to review all of them, especially there were books included. Therefore, I selected the 10% members of each community. The 10% were the ones with the highest degree centralities, which helped distinguish the nodes representative to the homogeneous networks[12]. After this threshold applied, the scope for this round of review cut down to 227 documents. I followed the 5-stage framework by Arksey and O'Malley (2005): 1) identifying the research question; 2) identifying relevant studies; 3) study selection; 4) charting the data; 5) collating, summarizing and reporting the results. Previous steps already covered the first three stages and left us on stage 4.

I used NVivo 12 to help with charting the data. In NVivo, I organized the documents according to their cluster number. Then, I created four codes (see *Appendix C* for the coding manual): 1) research questions, 2) theories & concepts, 3) methods & databases, 4) findings for each community. After carefully reading the abstracts and skimming through other relevant chapters (for books, prefaces, tables of contents, and/or introduction chapters) , I coded relevant sentences and paragraphs to the corresponding nodes, which resulted in a neatly organized chart. With the charted

[11] The step prior to this was to check if the co-citation network represented the reality or not. (if the communities we acknowledged their existence were reflected on the map). See the flowchart and section 3.4.

[12] On the premises that co-citation relationship indicates similarities between two documents, and the documents were clustered for the optimization of modularity, the local members in a community are homogenous.

data in hand, I was able to build a narrative for an exploratory-descriptive purpose on stage 5 by presenting the literature thematically. It is noted that the general scoping review requires less degree of “synthesis” than a systematic literature review, which means no attempts on quality assessment or finding aggregation (Arksey & O’Malley, 2005). The idea here was to outline the intellectual foundations. It aligned with the action of “mapping” in the co-citation network analysis.

Our third set of research questions were: what is the current state of sustainability topics in the field? And how can time use research promotes the understanding of sustainability? Answering this question required a more detailed scoping review, the second type as mentioned above. Having finished the general scoping, I was able to roughly determine if the map was representative to the reality based on whether the communit(ies) we knew their existence showed up on the network map. However, to understand the degree of representativeness, a small-scale manual testing was needed (see Section 3.4). The testing results showed that the sustainability literature did not cluster up as expected, but scattered in different communities. Alternatively, I reviewed the literature of interest we pulled out in a systematic manner. This round of scoping review aimed at identifying the research gaps and developing a theoretical framework. Following the same 5-stage framework but going beyond the exploratory fashion, I investigated the literature more thoroughly, compared contradicting evidence if possible, and attempted a certain level of “synthesis” on stage 5.

The two rounds of scoping were performed with the manual testing process in between. Below section explained the rationale and steps behind.

3.4 Manual testing

One focus of this study is the sustainability discourse on time use studies. I was curious to find out if the knowledge base of this specific field is covered in our collection of co-cited documents. The coverage would reveal the degree of

representativeness of the co-citation map to the academic world reality. I did a small-scale manual testing with five publications (see Table 3) familiar to the expert (Dr. Simron Singh[13]) of the sustainability/development time use studies. The five publications were considered by the expert as contributing work from the sustainability/ development field to time use research, especially Gross's (Gross, 1984) comprehensive review on time allocation studies. Similar but in a smaller scale to the earlier data retrieval steps, I extracted the lists of references of the five publications. Of the 726[14] in total, I first highlighted the common references (34), which were documents being cited by at least two of the five publications. With the remaining unique references, I then selected 162 [15]references with keywords such as "time", "labo(u)r", "work", "leisure"[16], or implying such notions in their titles. The two-step process left us a list of 196 references, and the selection was approved by the expert. Preconceiving these references as part of the knowledge base of sustainability time use studies, I then cross-checked with the co-cited documents to see if they were covered in the pool. Taking it one step further, I also went back to the Scopus database and documented if these cited references were indexed or at least listed as "secondary document"[17] by Scopus.

Additionally, we conducted a search with a list of sustainability-related keywords[18] in *title*, *abstract*, and *keyword* of all source articles. We also highlighted the ones triggered by the search in the co-citation network. The purpose of this step is to, first, find out whether the potential sustainability time-use work exists in the co-citation network; second, if so, whether they are still scattered or able to form into clusters. The results may further confirm or challenge our manual testing findings.

[13] Associate Professor from the Faculty of Environment, University of Waterloo, Canada; PhD in Human Ecology from Lund University, Sweden; Research focus on systematic links between material and energy use, time-use and human wellbeing.
[14] (Gross, 1984): 330; (Ringhofer et al., 2014): 67; (Fischer, 2015): 230; (Fischer-Kowalski & Haas, 2016): 69; (Smetschka et al., 2016): 30
[15] (Gross, 1984): 121; (Ringhofer et al., 2014): 6; (Fischer, 2015): 26; (Fischer-Kowalski & Haas, 2016): 3; (Smetschka et al., 2016): 6
[16] These keywords are the most frequent occurring ones in the titles of co-cited documents of our collection
[17] A secondary document is a document that has been extracted from a Scopus document reference list but is not available directly in the Scopus database since it is not indexed by Scopus.
[18] sustainability, sustainable, environmental, social ecology, socioecological, socio-ecological, sociometabelic, ecological economics, industrial ecology, energy, land, carbon, material and energy use, labour intensity, land-time budget

Table 3

Overview of the five articles used for manual testing

Title	Authors, Publication year
Time Allocation: A Tool for the Study of Cultural Behavior	Gross, 1984
Beyond Boserup: The Role of Working Time in Agricultural Development	Ringhofer et al., 2014
Changes in Societal Time Use as A consequence of Development Interventions in Turkana County, Kenya	Fischer, 2015
Time Use, Gender and Sustainable Agriculture in Austria	Smetschka et al., 2016
Toward a Socioecological Concept of Human Labor	Fischer-Kowalski & Haas, 2016

3.5 Content-similarity network analysis

To fully understand the current state of sustainability topics in the time use field and how time use research is able to advance sustainability discourse, we triangulated our research method by experimentally exploring a content-similarity network analysis based on an extensive body of abstracts. The analyzed abstracts contain those from the original dataset, the five articles in the table, one recent published review article by Wiedemhofer, et al., (2018[19] in the Journal of Current Opinion in Environmental Sustainability), and the six articles' relevant references.

We pre-processed the text that included high-frequency removing stop words process. As a result, each abstract was reduced to a vector of nouns (the corpus). Then, we computed weight words by TF-IDF, which process penalized words being too frequent or too rare. We computed the cosine similarity of every pair of documents in the corpus and converted the similarity to 0 if the cosine similarity is less than 0.5. Following that, we converted the similarity matrix to an adjacency matrix that can be used to generate an undirected document network. The nodes are articles from the original search or our input six articles and their extended

[19] Wiedemhofer et al (2018) caught our attention after we completed the manual testing. Although we did not replicate the manual testing process with the inclusion of this article, some quick search indicated the absence of most of its references in our original pool, similar to the situation of the five articles'.

references. The edge strength represents the similarity of content. Similar to the co-citation network, we used Louvain modularity-based community detection algorithm to partition the network. This series of programming was again conducted by Dr. John McLevey. The practice is far less common than the co-citation network analysis. However, the novelty of drawing similarity from abstracts rather than references fed to the method triangulation purpose. We attached the codes in *Appendix B*.

After the content-similarity network being generated, we performed a brief scoping review on the largest 10 communities in an attempt to capture the underrepresented sustainability theme(s). We discussed the results in the next chapter.

4. Results and Discussion

This chapter is also organized following the order of the 5-step analysis. Section 4.1 presents the field delineation results on the research fronts. Section 4.2 overviews the co-citation network and identifies the pivotal intellectual foundations. Section 4.3 and 4.5 are scoping reviews on the top 10 largest communities, and the identified sustainability community, respectively. The in-between section 4.4 shows the manual testing results, which are also used to determine what the detailed scoping review should be conducted on.

4.1 Analysis of the research front

A total of 3063 journal articles were captured by our advanced search in Scopus. They serve as building blocks of the time use research front. Due to the limitations of our semi-manual data screening, the citing article data collection still includes minimal amount of articles irrelevant to our time use focus. Therefore, figure 4 with 3009 data points shows the evolution of the time use field from 1963 to 2017, which excludes the four mis-captured articles published before 1963, the incomplete article count records (46) for 2018, and six articles with no publication years properly indexed. The left Y axis represents the annual article counts and the right Y axis is for the cumulative counts. The evolution of this field can be divided into three periods: the incubation period (1963-1989), the fluctuation period (1990-2003), and the explosion period (2003-). Before the 1990s, the field is growing slowly with annual mean contribution of around seven and accumulation of only 155 articles till 1989. It follows by a moderate growth with constant fluctuations until 2003 before experiencing a exponential growth, reaching the first peak in 2011 (200), and climbing to the highest (244) in 2016. The annual counts of 2017 has dropped by roughly 14%, showing a potential downward trend for the coming years. The total accumulation for 1963 to 2017 is 3009, as already indicated above.

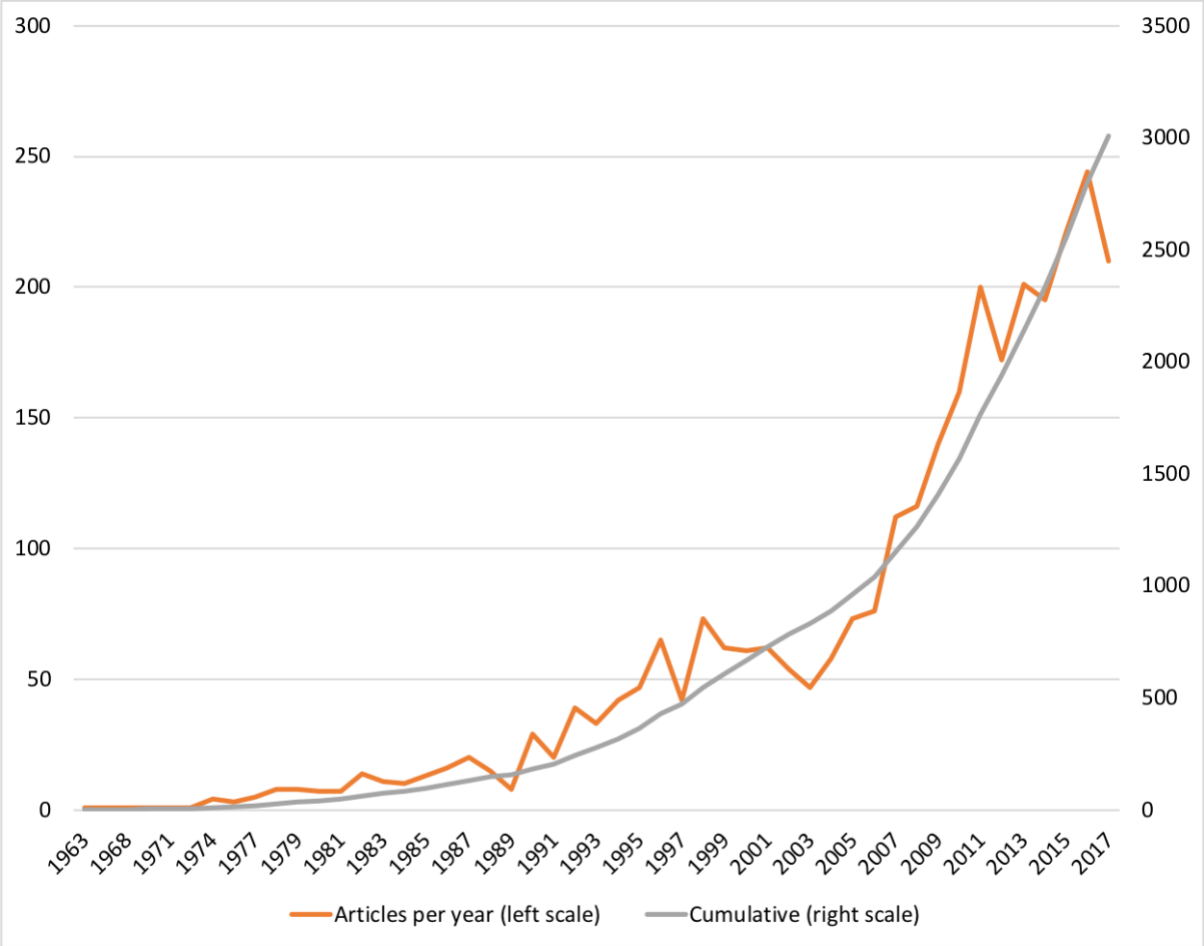

Figure 4. Annual publication counts of time use research from 1963 to 2017 in Scopus

The top journals that published the 3063 time use research articles, ranked by the article counts, are Time & Society[20] (458 records), Social Indicators Research (95), Journal of Marriage and Family (54), Review of Economics of the Household (46), Transportation (40), Feminist Economics (36), Transportation Research Record (33), and Journal of Family and Economic Issues (29). The journal, Time & Society, which we fully included all issues[21] indexed in Scopus, occupies nearly 15% of the pool. The second is Social Indicators Research (3.10%), which has a general profile of

20 Also indexed as "Time and Society" under the same source ID in Scopus
21 The coverage of time and society

social sciences. The rest top journals each share around 1%. Among the eight journals, Journal of Marriage and Family, an anthropology- specialized journal, has the highest CiteScore for 2017, indicating high impact based on its received citations, according to Scopus (Scopus, 2018). The close second is Transportation (2.85), a journal that advances understanding on all aspects of transport systems (Scopus, 2018). The CiteScore 2017 for Time & Society is 0.99, the second lowest among the eight (Scopus, 2018). According to the source detail page of this journal in Scopus, it is ranked 311 among the 1028 journals under the subject category of social sciences: sociology and political science (Scopus, 2018).

Table 4. shows what fields and subject areas these main journals fall into. The dominant subject subject area of time use research is social sciences & humanities, including fields such as sociology and political science, anthropology, psychology, economics, transportation, and gender studies. The only two fields categorized under physical sciences are civil and structural engineering, and mechanical engineering, for the two transportation-specialized journals.

Table 4

Top journals publishing time use research (1927-2018[22])

Journal	**Field(s)**	**Subject area(s)**
Time & Society (Time and Society)	Social Sciences: Sociology and Political Science	Social Sciences & Humanities
Social Indicators Research	Social Sciences: General Social Sciences; Social Sciences: Sociology and Political Science; Arts and Humanities: Arts and Humanities (miscellaneous); Psychology: Developmental and Educational Psychology	Social Sciences & Humanities

22 We did not exclude data before 1963 and in 2018 as we did for the time series plot, mainly because those data points had insignificant effects on the counting of top journals. Same for the top authors.

Journal of Marriage and Family	Social Sciences: Anthropology Social Sciences: Social Sciences (miscellaneous) Arts and Humanities: Arts and Humanities (miscellaneous)	Social Sciences & Humanities
Review of Economics of the Household	Social Sciences: Social Sciences (miscellaneous) Economics, Econometrics and Finance: Economics and Econometrics	Social Sciences & Humanities
Transportation	Social Sciences: Development; Engineering: Civil and Structural Engineering; Social Sciences: Transportation	Social Sciences & Humanities Physical Sciences
Feminist Economics	Social Sciences: Gender Studies; Business, Management and Accounting: General Business, Management and Accounting; Economics, Econometrics and Finance; Economics and Econometrics; Arts and Humanities: Arts and Humanities (miscellaneous)	Social Sciences & Humanities
Transportation Research Record	Engineering: Civil and Structural Engineering; Engineering: Mechanical Engineering	Social Sciences & Humanities Physical Sciences
Journal of Family and Economic Issues	Economics, Econometrics and Finance; Economics and Econometrics; Psychology: Social Psychology	Social Sciences & Humanities

Table 5 depicts the top authors ranked by the article counts in the sample, as well as the most relevant three fields they work in, according to Scopus. All nine authors, who contribute to building the time use research front, have worked in some aspects

of the social sciences. Besides the general social science, some active fields they have worked in this subject area include 1) business, management and accounting; 2) economics, econometrics and finance; 3) decision sciences; 4) psychology. However, physical sciences (engineering, computer science) and health sciences (biochemistry, genetics and molecular biology, medicine, nursing) are also parts of their research backgrounds, making more appearance than in the top journal profiles. The top three contributors to this field are sociologist Craig, L. (31 article counts), transportation engineer Bhat, C.R. (27), and sociologist Gershuny, J. (tied, 27). The two sociologists share similar research interests pertaining to time use, such as gendered division of labour and quality of life, while Bhat, C.R. has been modeling travel demands borrowing a time use perspective to understand travel behaviors. Another example of novel implications of time use data is Stange, K.C.'s research on public health practices from an understanding of how time is spent during outpatient visits.

Table 5

Top authors publishing time use research (1927-2018)

Ranking	Author	Fields	Article count
1	Craig, L.	Social Sciences; Business, Management and Accounting; Economics, Econometrics and Finance	31
2	Bhat, C.R.	Engineering; Social Sciences; Decision Sciences	27
2	Gershuny, J.	Social Sciences; Business, Management and Accounting; Economics, Econometrics and Finance	27
3	Robinson, J.P.	Social Sciences; Biochemistry, Genetics and Molecular Biology; Computer Science	25
3	Bittman, M.	Social Sciences; Business, Management and Accounting; Medicine	23

4	Sullivan, O.	Social Sciences; Economics, Econometrics and Finance; Psychology	20
5	Gimenez-Nadal, J.I.	Economics, Econometrics and Finance; Social Sciences; Business, Management and Accounting	19
6	Glorieux, I.	Social Sciences; Psychology; Engineering	16
6	Stange, K.C.	Medicine; Nursing; Social Sciences	16

Table 6. lists the top references cited by the time use research front in the collection. The top three are *A note on recent changes in time use* (Juster, 1985), *Time for life: the surprising ways Americans use their time* (Robinson & Godbey, 1997), and *The validity and reliability of diaries versus alternative time use measures* (Robinson, 1985). The article by Juster (1985) and the one by Robinson (1985) were published in the book *Time, goods, and well-being* (Juster, 1985). The book explores the time use research methods (Part 1), lays a conceptual framework (Part 2), and also experiments with time use data to modeling individual and household behaviours (Part 3) (Juster, 1985). *A note on recent changes in time use* (Juster, 1985) is a study that compares the time use structures among American households between the time periods of 1975-1976 and 1981-1982. The findings indicate that the gendered division of labour and household work has been "weakened", especially among the younger populations (Juster, 1985). Robinson's article (1985), in contrast, is entirely on the methodology side of time use research by assessing the validity and reliability of time diary data. This work has received a lot of credits from following studies that incorporate time use diaries as their method, but here we will not touch the technical methodology issues. Robinson also co-authors the book *Time for life: the surprising ways Americans use their time* (1997). This book does a cross-time comparison among 1965, 1975, and 1985 time diary datasets from the American's Use of Time Project. It suggests that more time was freed for men on paid work and for women on household work, evident from the time declines on activities of corresponding categories, in 1985 than in previous two survey years, despite that the generations reported to perceive more time pressure than before (Robinson &

Godbey, 1997; Townsley, 1998). This central argument challenges the previous belief that Americans are working longer hours, and therefore have less free time than before (Schor, 1991). The theme of time pressure perceptions (discussed in Part 5 of the book) is later picked up by sociology, anthropology, and social psychology studies on work, leisure, family-work balance, and subjective well-being, etc. To summarize, these publications, to a greater or lesser degree, lay the foundations of time use research. We will see more clearly on how the knowledge base of this field unfolds in the document co-citation network analysis.

Table 6

Top cited references cited by time use research front

Title	First Author	Pub. year	Source
A note on recent changes in time use	Juster, F.T.	1985	Time, goods and well-being
Time for Life: The Surprising Ways Americans Use Their Time	Robinson, J.P.	1997	/
The validity and reliability of diaries versus alternative time use measures	Robinson, J.P.	1985	Time, Goods, and Well-being
Changing Times: Work and Leisure in Postindustrial Society	Gershuny, J.	2000	/
The Rush Hour: the Character of Leisure Time and Gender Equity	Bittman, M.	2000	Social Forces
A theory of the allocation of time	Becker, G.S.	1965	Economic Journal
The allocation of time: Empirical findings, behavioral models, and problems of measurement	Juster, F.T.	1991	Journal of Economic Literature
A survey method for characterizing daily experiences	Kahneman, D.	2004	Science

Is Anyone Doing the Housework? Trends in the Gender Division of Household Labor	Bianchi, S.M.	2000	Social Forces
Changing rhythms of American family life	Bianchi, S.M.	2006	/
Maternal employment and time with children: dramatic change or surprising continuity?	Bianchi, S.M.	2000	Demography
Are parents investing less in children? Trends in mothers' and fathers' time with children	Sayer, L.C.	2004	American Journal of Sociology
Economic dependency, gender, and the division of labor at home	Brines, J.	1994	American Journal of Sociology
A theory of time allocation	Becker, G.S.	1965	The Economic Journal
Time, Work-discipline and Industrial Capitalism	Thompson, E.P.	1967	Past and Present
When Does Gender Trump Money? Bargaining and Time in Household Work	Bittman, M.	2003	American Journal of Sociology
Time and Social Theory	Adam, B.	1990	/
Measuring trends in leisure: The allocation of time over five decades	Aguiar, M.	2007	Quarterly Journal of Economics

4.2 Analysis of the document co-citation network

This study aims at unfolding the intellectual foundations of the field of time use research through co-citation network analysis. Section 4.2.1 presents the overview of the co-citation network structural features. Section 4.2.2 lists the publications with high eigenvector and betweenness centrality scores in the network. It is fair to say that these publications lay the foundations for the field.

4.2.1 Overview of the research clusters

There are 3206 nodes in the co-citation network of the time use research field, which means the same number of cited documents; 9653 edges, the co-citation links. The network has a density of 0.00188 and a transitivity of 0.22, which two metrics, on a scale of 0 to 1, measure how well-connected and transitive the network is. After Louvain algorithm applied, the network is decomposed into 134 clusters with a fixed resolution of 1.0, labelled from 0 to 133. Among the 134, the top 10 largest clusters, each of which has at least 50 members (documents), covers 70.8% (2270/ 3206 documents) of the entire network. They constitute the large components, and are located in the central of the graph. Small clusters scatter around them like a ring system of a planet. Figure 5 shows the central part of the document co-citation network. The top 10 largest communities are in colours.

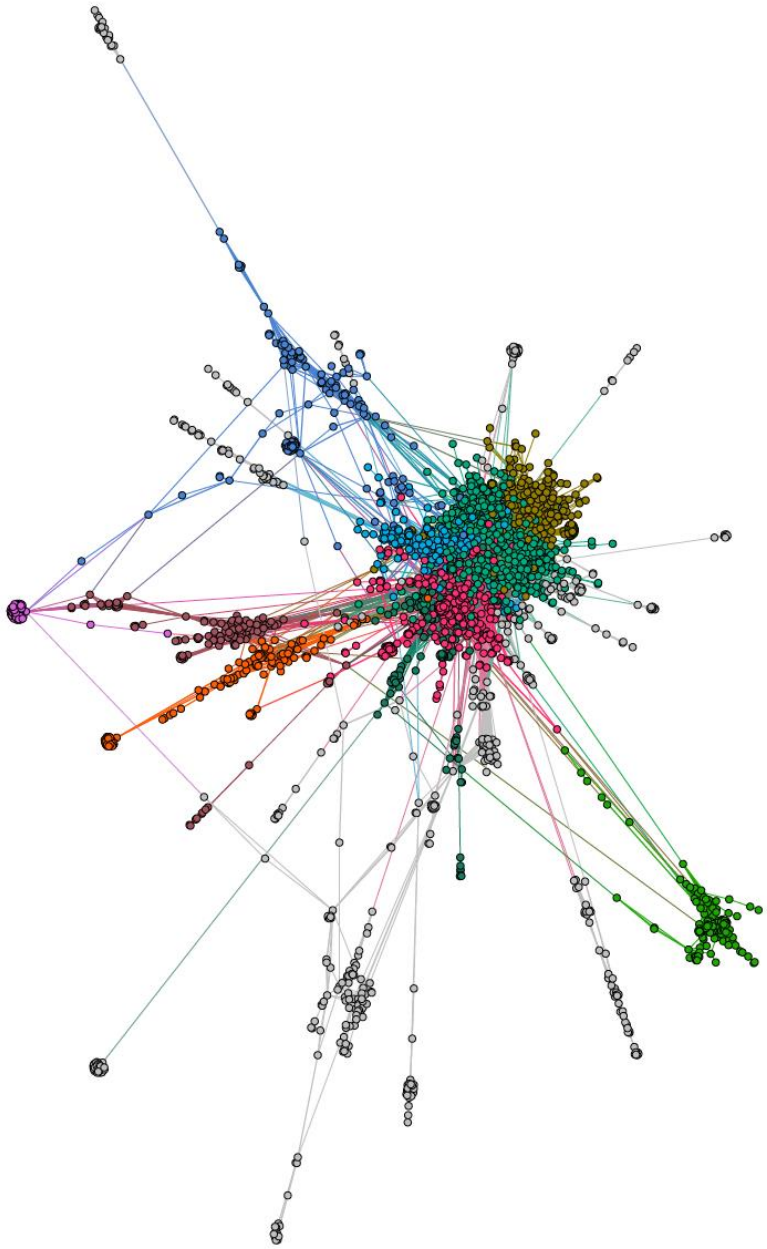

Figure 5. Co-citation network of the time use research field (non-labelled)

4.2.2 Key publications

In network analysis, centrality is a measure of nodes. Nodes attributed with high eigenvector centrality scores are considered as influential to the network; those with high betweenness centrality scores are pivotal because they bridge different clusters. Applying this understanding to our unit of analysis, publications: we are

especially interested in publications with both high eigenvector and betweenness centrality scores.

Figure 6. depicts the betweenness/ eigenvector centrality plot of all publications in our co-cited network. It shows that most publications have rather low scores in terms of both. There are some publications with mismatched scores: eigenvector significantly higher than betweenness, and vice versa. It is perfectly understandable that some publications are only influential in their own communities, or the others connect different communities but themselves have fewer impacts on the whole network. A couple of nodes stand out because of their high betweenness centrality scores coupled with moderately high eigenvector scores (see top right of the figure).

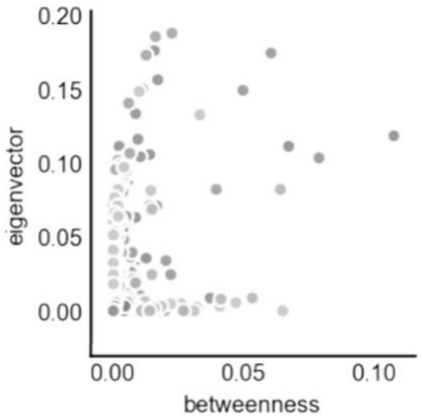

Figure 6. The betweenness/ eigenvector centrality plot

In Table 7, we listed the top publications with a descending order of their betweenness centrality scores, which also have an eigenvector score higher than 0.01. We deliberately omitted those with low eigenvector (threshold set as 0.01). For example, *Fundamentals of Neuropsychology* (Kolb, 2003) is in the highest betweenness centrality list, but only a 0.000214 eigenvector score. The 6 articles included in the final list all appear to be the top cited references in time use research..

Table 7

Top publications with the highest betweenness centrality scores, and eigenvector centrality scores above 0.01

Publication	Cluster[23]	Betweenness	Eigenvector
Time, goods and well-being (Juster & Stafford, 1985)	0	0.107325	0.118863
Time for Life: The Surprising Ways Americans Use Their Time (Robinson, 1997)	0, 3	0.078592	0.103721
The validity and reliability of diaries versus alternative time use measures (Robinson, 1985)	0, 9	0.067283	0.111605
A survey method for characterizing daily experiences (Kahneman et al., 2004)	3	0.064031	0.082272
The Rush Hour: the Character of Leisure Time and Gender Equity (Bittman & Wajcman, 2000)	1	0.060255	0.174471
Changing Times: Work and Leisure in Postindustrial Society (Gershuny, 2000)	0, 3, 10	0.049813	0.149423

4.3 Scoping review on the major clusters

Among the 134 clusters, we focused on the largest ten and labelled them if they have a cohesive theme(s). Below is a detailed review on some distinctive communities labelled as household economics (Cluster[24] 0), childcare (Cluster 1&10), consumer behaviour (Cluster 4), and transportation (Cluster 2).

There are some recurring themes in the co-citation network, namely household economics, sexual division of labour, well-being, consumer behaviour, and

[23] The number assigned to each only serves as an identification purpose, and therefore, does not hold any quantitative values. Because of the duplicates, the articles appear in multiple communities.
[24] We used “cluster” and “community” interchangeably in context. For differentiation, “cluster X” is used for labeling the co-citation network, while “community X” for the content-similarity network.

transportation. Two distinctive communities, Cluster 14 and 43, the former of which is a multidisciplinary cluster in youth and adolescence studies, and the latter is a psychological subset exclusively discussing “boredom” and its psychometric measures. According to our co-citation network, the youth and adolescence cluster has some ties to the “mainland” while the “boredom” being somewhat an outlier (condensed in its own). We aim to focus on the cohesive themes that are not characterized by the focus of certain demographics, thus leaving out the discussion of these two communities. *Figure 7*[25] depicts the co-citation network labelled with the themes.

[25] The Louvain algorithm in Gephi, our visualization software, is slightly different from the one we ran in Python. Therefore, the largest 10 communities in the graph are NOT identical to the ones analyzed using Metaknowledge (python), although very similar. We labelled the graph with the themes, and did not assign community number to each to ensure accuracy.

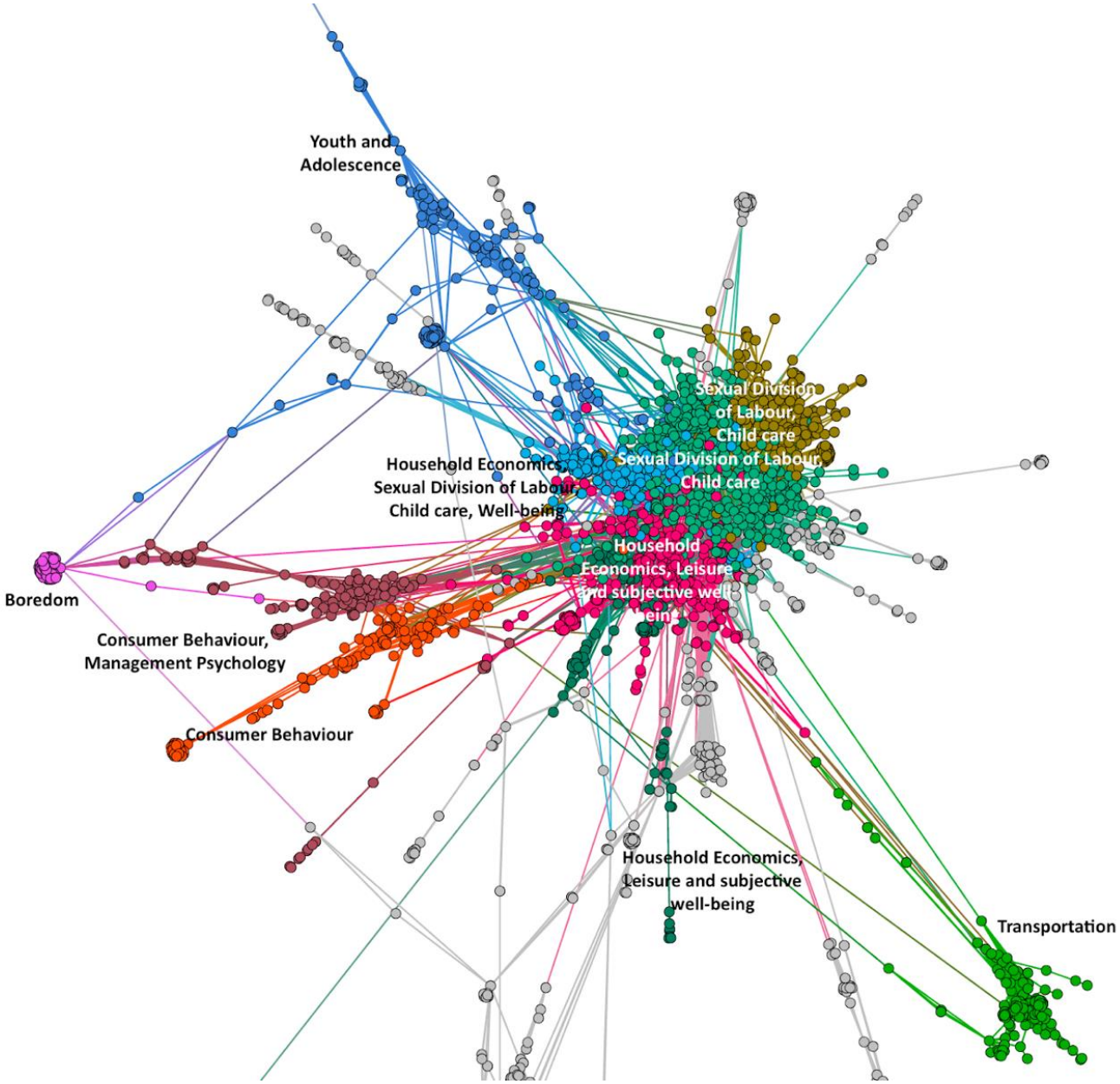

Figure 7. Co-citation network of the time use research field (labelled & zoomed-in version)

4.3.1 Household economics, leisure and subjective well-being

Theme label(s): Household Economics, Leisure and subjective well-being
Discipline(s): Economics, Sociology

Cluster 0:

Cluster membership: 283
Median year: 1991
Sample size: 15 journal articles and 13 books (or book chapters)
Main topic(s): time allocation theories, household production models,

With 283 cluster members and a median year of 1991, cluster 0 is the second largest and the second oldest among the top 10 communities. This cluster is interdisciplinary with contributors from domains of economics and sociology. Having included some pivotal publications on time use, such as *Time, Goods, and Well-being* (Juster, 1985), *The Surprising Ways Americans Use Their Time* (Robinson, 1997), and *The Validity and Reliability of Diaries Versus Alternative Time Use Measures* (Robinson, 1985), cluster 0 lays the foundations for the field of time use research. The top 10% of the documents with the highest degree centralities were chosen as our sample for the scoping review. They are 13 books (or book chapters) and 15 journal articles. A search on WorldCat suggests that the 13 books hold a wide range of subject interests, such as sociology, social indicators research, household economics, and political economics. Similarly, the 15 journal articles are an aggregate set of interdisciplinary papers with theoretical, methodological, and empirical contributions to the field of time use research. In this paper, we focus on the conceptual foundations established by cluster 0.

In the book *The Use of Time: Daily Activities of Urban and Suburban Populations in Twelve Countries*, Szalai (1972) defines “time-budget research”, which we deem as an interchangeable term to “time use research” in most occasions, as a body of studies interested in temporal, spatial, and social attributes of daily activities. In simple terms, they study “who does what (what else simultaneously during the day, for how long, how often, at what time, in what order, where, and with whom)” (Szalai, 1972, p.5). Time carries similar characteristics as monetary resources that can be “budgeted” according to preferences and restraints. However, unlike money, time is finite. Also, it can only be consumed not purchased (Szalai, 1972). Economists and sociologists are two main contributors to this field, as indicated in the sample of cluster 0.

Economists' interests in time use steam from the inadequate accounting of material well-being (Juster, Courant, & Dow, 1985). They argue that the traditional economic accounting systems neglect the exchanges of flows and stocks happening with the household unit (Juster et al., 1985). New Household Economics, founded by Gary Becker and his colleagues at Columbia University, emerged to address this boundary concerns. In Becker's classic paper, "A Theory of the Allocation of Time" (1965), he treats households as both consumers and producers. Households produce "commodities" with the inputs of goods and time to maximize household utilities. The quantity of household production is determined by the commodity price and a constraint on resources (Becker, 1965). In his model, time and goods can be combined into a single resource constraint function because of the trade-offs. He (1965) explains that the trade-off happens when time is spent more at work and less at leisure (consumption), in the sense that time is converted into goods. The constraint is expressed as "full income", which is the sum of money income and earnings "forgone" in non-market hours (Becker, 1965). This paper is of no doubt an influential work being widely cited in the field of time use research. He was honoured with the Nobel Prize in Economics for "extend(ing) the domain of economic theory to aspects of human behaviour which had previously been dealt with by other social science disciplines such as sociology, demography and criminology" (Nobel prize, n.d.). However, Gronau (1977) criticizes Becker's model for aggregating housework and leisure time in one unit, non-market time. Consequently, he concluded that Becker's model is insufficient for understanding household behaviours. Other models, such as Gronau's (1977) and Kooreman and Kapteyn's (1987), claim to be more empirically applicable to understanding household production for their attempt on disaggregation. Another limitation of Becker's model is the lack of consideration of the division of labour within households. He addresses this limitation in his later work "Human Capital, Effort, and the Sexual Division of Labor" (1985), where he discusses the theory of "specialization". This paper serves as a theoretical starting point for researchers interested in household division of labour, and it is included in cluster 1 in our collection.

Other social scientists, mainly sociologists, extend the scope of "well-being" to include the subjective satisfaction, so called "quality of life". They attempt to develop a set of social indicators that measure "the degree to which society produces results

that generate satisfaction for its members" (Juster et al., 1985). Such indicators are usually direct or indirect measures of leisure time, and often intended to inform social policies. Cluster 0 includes some important work from this strand of research. For example, Vickery (1977) developed a two-dimensional scale to incorporate time resources for measuring poverty status of households. Some similar works of this school are not in the sample but the collection, such as Beckerman (1978), Campbell, Converse, and Rodgers (1976), etc.

Another common theme brought to attention by scholars on leisure studies, is "time pressure". Linder (1970) in his book *The Harried Leisure Class* and Schor (1991) in hers *The Overworked American: The Unexpected Decline of Leisure* send out the same message that leisure becomes rushed in post-industrial societies, even though time use diaries of the same period of time suggest an increase in leisure time (Robinson & Godbey, 1997). Linder (1970) explains the phenomenon is partly because the productivity of working hours has been increased, thus the productivity of leisure time is pressured to match.

Juster et al. (1985) summarize the early development of time use research as attempts to measuring the material inputs by economists, and ultimate outcomes by sociologists, without a systematic understanding of how time allocation affects individual and societal well-being at the intermediate stages. In the book *Time, Goods, and Well-being*, the authors develop a conceptual framework that centralizes "time use" to fill in the gap (Juster, 1985). They treat time allocation as a mediator between material inputs and ultimate outcomes (Juster et al., 1985). The current state of the world, expressed in "stocks" and "contexts", is constantly altered by time use at some rates of flow (Juster et al., 1985). In addition to the obvious tangible outcomes of time use, they specifically acknowledge two subjective ones: "process benefits" and the "evaluation of the state of the world" (Juster et al., 1985, p. 121). The "process benefits" operationalize the satisfaction towards different activities, regardless of the associated material outputs (Juster et al., 1985). The evaluation of the state of the world is described as a result of previous time use (Juster et al., 1985). For example, individual and societal well-being might be influenced by water pollution resulted from certain activities happening in the past. Their social accounting system is elaborated in details in Chapter 6 of the book.

Besides the conceptualization of time use, cluster 0 also devotes to the development of data collection methods (e.g., Juster, Ono, & Stafford, 2003; Kan, 2008; Robinson, 1985) and establishment of standardized international datasets such as the Multinational Comparative Time-Budget Research Project (Szalai, 1972). With the increasing availability and accessibility of large-scale datasets, Andorka (1987) in his review article on time use research summarizes common themes in this field: 1) mass media; 2) urban planning; 3) consumer behaviour; 4) child care and elderly care; 5) sexual division of labour; 6) informal economy and household economics; 7) social indicators, quality of life, well-being; 8) lifestyle; 9) social structure; and 10) intertemporal and international comparison. The empirical studies in the sample of cluster 0 seem to concentrate on 5), 6), and 7). Other themes generally spread in the remaining clusters, even though some of them are clearly underrepresented in our collection. This section is organized following such theme labels, where applicable.

4.3.2 Sexual division of labour and child care

Theme label(s): Sexual Division of Labour, Child Care
Discipline(s): Sociology, Demography

Cluster 1:
Cluster membership: 306
Median year: 2004
Sample size: 24 journal articles and 7 books (or book chapters)
Main topic(s): gender division of unpaid work, child care, work-family

Being the largest cluster with 306 members, cluster 1 has a strong focus on child care and family time from a sociology perspective. The sample of 31 documents consist of 24 journal articles and 7 books (or book chapters). Different from cluster 0, the WorldCat search for the seven books in this cluster shows a convergent subject interest on work and family. The results align with the word frequency search in NVivo, which lists timing, children, parents, child, caring, and family as the most frequent words used in this cluster.

The median year of all publications is 2004. Based on the scoping review of the sample, most of them explore the phenomenon that more women have been participating in paid labour force, thus emerging dual-earner families, in Western developed countries since the mid of the 20th century. How did the economic shift affect the gender division of time, especially towards child care? Two contested theories were borrowed in cluster 1 to establish hypotheses: the cooperative economic/ bargaining perspective and the gender perspective. The former suggests that women's increasing involvement in paid work and contribution to household earnings "buy" them "bargaining power" out of unpaid work (Blau, 1998 cited in Sayer, 2005; Goldscheider & Waite, 1991, Lundberg & Pollak, 1997 cited in Yeung et al., 2001), while the latter argues that the division of work continues to reinforce the gender role expectations when women and men will do gender by doing more or less unpaid work, contrary to rational decisions around resources held by the former economic-based perspective (Berk, 1985 cited in Hook, 2006; Thompson & Walker, 1995 cited in Sayer, 2005). Therefore, several common research questions arise in this community: 1) whether women's increased employment undermines the quantity and quality of their child care time (e.g., Bianchi, 2000; Craig, 2006; Gauthier, Smeeding, & Furstenberg, 2004); 2) whether and how men (fathers) reallocate their time accordingly (e.g., Craig, 2006; Hallberg & Klevmarken, 2003; Hook, 2006; Hook & Wolfe, 2012; Raley, Bianchi, & Wang, 2012; Yeung et al., 2001); 3) beyond the measure of total time, what the child care/ family time is conceptualized and composited of across sections (e.g, Craig, 2006; Daly, 2001; Folbre et al., 2005; Zick & Bryant, 1996); 4) whether subjective perceptions of time pressure, seemingly far from the actual increases in child care and leisure time, is gendered (Bittman & Wajcman, 2000; Mattingly & Bianchi, 2003; Mattingly & Sayer, 2006; Milkie et al., 2004) and 5) whether and how the changes affect dual-earner couples' time together (e.g., Kingston & Nock, 1987; Lesnard, 2008; Sullivan, 1996). Also, besides the economic changes, some literature investigates how demographic (e.g. fertility, parental education, family structure) (e.g. Kalil et al., 2012; Sandberg & Hofferth, 2001; Sayer, Gauthier, & Furstenberg, 2004), normative factors (e.g. parenting behaviours) (e.g., Sandberg & Hofferth, 2001; Sayer, Bianchi, & Robinson, 2004), and national policies (e.g., Hook, 2006) come into play.

The availability of large-scale time use surveys enables researchers to answer these questions by making cross-sectional, intertemporal, and/ or international comparisons. In the American context, national time use surveys are conducted on an approximately 10-year basis[26] even before the launch of American Time Use Surveys (ATUS) in 2003. Australian Bureau of Statistics Time Use Surveys are widely adopted because of their details on secondary activities and inclusion of all household members above the age of 15. Cross-national studies generally draw their data from the Multinational Time Budget Data Archive (Gershuny, 1990) and the Multinational Time Use Study (MTUS) surveys. Specialized datasets with a focus on parental and children's time use include 1997 Child Development Supplement of the Panel Study of Income Dynamics (PSID-CDS)[27].

Findings in cluster 1 suggest that 1) women's increased involvement in paid labour force has decreased *neither* quantity *nor* quality of child care (Bianchi, 2000); 2) mothers' child care time is positively related to their educational level and higher educated mothers tend to tailor child care time to children's development needs in different life stages (Kalil et al., 2012); 3) fathers' participation in child care has overall increased and a more egalitarian "new father" role is emerging in intact families on weekends (Hook & Wolfe, 2012; Yeung et al., 2001); 4) however, mothers still bear the larger components of child care, which also involve more double activities and physical labour (Craig, 2006); 5) Parents' time with children has overall increased in the 1990s than before partly due to behavioural changes, which may support the thesis that parents tend to desire fewer children of higher "quality" (Gauthier et al., 2004) and 6) the experience of time pressure differs mostly in quality among men and women found in Bittman and Wajcman's analysis of Australian data (2000) while the empirical findings based on American data show that men enjoy not only higher quality but also more leisure time (Mattingly & Bianchi, 2003). The findings summarized above are only the tip of the iceberg of the empirical contributions made by cluster 1. However, it is worth noting that this community mainly speaks to the industrialized Western societies[28]. Main

[26] see appendix table A1 in Sayer, Bianchi, and Robinson (2004) for methodological comparisons
[27] See "Data and Methods" section in Sandberg and Hofferth (2001) for reviews on these datasets
[28] See "A note on developing countries" in Bianchi (2000)

contributors[29] to this cluster include Bianchi, S. (14 counts[30]), Bittman, M. (4), Hofferth, S. (7), Lesnard, L. (5), Milkie, M. (4), Presser, H. (5), Sayer, L. (4), and Sullivan, O. (9).

Cluster 10:
Cluster membership: 213
Sample size: 15 journal articles (4 articles repeated in Cluster 1) and 7 books (2 books repeated in Cluster 1)
Median year of the sample: 2005
Main topic(s): sexual division of unpaid work, child care, work-family

Cluster 10 shares the same academic roots as cluster 1. The focuses on gender division of unpaid work are almost identical. After comparing the samples of the two communities side by side, we find that there are 6 documents repeated due to the method limitation (discussed in the next chapter), namely, Bianchi (2000), Bianchi (2006), Craig (2006), Jacobs and Gerson (2004), Sayer, Bianchi, and Robinson (2004), and Sayer (2005). From the list, we can already see some overlapped names between the two clusters, such as Bianchi, S., Sayer, L. etc. In fact, this cluster evolves mostly around Craig, L.'s work (18 counts) and eight of them are in the sample, which translates to a high representativeness of the entire cluster. Cluster 10 has a median year of 2005 for the sample, only one year younger than cluster 1. With a continuing focus on gender division of household work, child care, and work-family conflicts, this cluster extends the debate on whether the dramatic increase in women's employment provokes a "second shift" for working mothers (Hochschild & Machung, 1989; Schor, 1991) or an equal share between the two genders. For example, the journal article entitled "Is there really a second shift and if so, who does it? A time-diary investigation" by Craig (2007) challenges the common practice of solely accounting the primary activity in time use measurement, which results in a similar share of total workload between the two genders. She suggests that a "second shift" exists in the form that women are not only shouldering most

29 Listed in alphabetical order of the last name, same below
30 May include duplicates, same below

unpaid work, but also working longer total hours, when the secondary activity, which child care is largely categorized into, is included in the total workload account (Craig, 2007). This is consistent with Bittman (2000) in cluster 1 that investigates the "second shift" claim in the dimension of leisure time, which shows the quantity is similar but the quality is lower for women partly because their leisure time is more "contaminated". From a subject speciality perspective, it is safe to say the two communities are almost identical, and the fragmentation can be concluded to the methodological limitation. Similarly, among the top 10 largest clusters, cluster 5, a smaller cluster with a median year of 2000, shares the same school of thought as the two mentioned above.

4.3.3 Consumer behaviour and management psychology

Theme label(s): Consumer Behaviour, Management Psychology
Discipline(s): Psychology, Sociology

Cluster 4:
Cluster membership: 248
Median year: 1995
Sample size: 19 journal articles and 6 books (or book chapters)
Main topic(s): Time perceptions, Polychronic time use, Consumer behaviour

Cluster 4 has a 248 members and a median year of 1995 for all publications. The sample selected has 19 journal articles and 6 books (or book chapters). Contrast to economists' conceptualization of time merely as a "resource" that can be budgeted in a rational manner, this community explores further how time is socially constructed, perceived, and managed. The subject tags for the six books on WorldCat indicate a sociological and psychological lens this community apply to time use.

"Time", understood by the previous communities, is mostly "clock time" in a Western cultural context. This objective concept of time is characterized as unitary, linear, and mechanical (Bluedorn & Denhardt, 1988). Popularized by Marx's thoughts, time is treated as money in the sense that labour time can be commoditized in the market.

However, this community has attempted to enrich the conceptualization of "time", especially in a subjective manner. The subjective dimensions of "time" acknowledged by this community include: *time perceptions* of individual (e.g., Bond & Feather, 1988; Hornik, 1984; Southerton, 2006) and cultural differences (e.g., Graham, 1981; Manrai & Manrai, 1995; Thompson, 1967), *time use patterns* (polychronic-monochronic orientations) (e.g., Bluedorn, Kaufman, & Lane, 1992; Conte, Rizzuto, & Steiner, 1999; Kaufman, Lane, & Lindquist, 1991)[31]. By adding these attributes, this community is able to investigate whether and how time affects behaviours and attitudes towards consumption (e.g., Graham, 1981; Hornik, 1984; Jacoby, Szybillo, & Berning, 1976; Kaufman et al., 1991; Strober & Weinberg, 1980), group management and organization (e.g., Bluedorn & Denhardt, 1988; Bluedorn et al., 1992; Kaufman & Lindquist, 1999; Tietze & Musson, 2002), as well as work and leisure perceptions in general (e.g., Manrai & Manrai, 1995; Thompson, 1967). In addition, the phenomenon of social acceleration has also been explored (e.g., Rosa, 2003; Southerton, 2003), which echoes the thoughts in some work in cluster 0 (e.g., Linder, 1970). Below, we present some findings on time perceptions and polychronic time use in the context of consumer behaviours.

To discuss time in consumer behaviour research, Jacoby et al. (1976) establish a terminology system to describe so-called time-consumer behaviour relationship. Similar to other communities, they assume time is finite, valuable, and can only be tradable through other resources, such as money (Jacoby et al., 1976). Situating in the consumer behaviour context, they also acknowledge that time can be both a dependent and independent variable in any stages of consumption (Jacoby et al., 1976). For the objective aspects, they develop points-spans-intervals and frequency-duration-extension-velocity, two sets of vocabulary that expand the ones in the traditional time use survey[32] (Jacoby et al., 1976). In addition to that, they attach a temporal dimension to products and external environment, for example, lifecycle of a product (Jacoby et al., 1976). They also develop vocabulary to portray consumers' subjective states, such as "urgency", "perceived newness", along with "anticipated

31 Time perceptions and time-activity are just two temporal dimensions that are widely mentioned in this community. Also, the two are intertwined in some context, hence, they can affect each other.

32 See detailed description in (Jacoby et al., 1976, p. 333-335)

frequency, duration, and extension" (Jacoby et al., 1976, p. 335). This terminology system has demonstrated early attempt to systematically study time-consumer behaviour relationship because prior to any deeper investigation is developing a language for accurate descriptions. Similarly, Hornik (1984) acknowledges the effects of time perceptions on consumer behaviours. The results of his study show that consumers tend to overestimate passive durations, such as waiting time (Hornik, 1984). He suggests time use researchers to incorporate a mixed-method approach that incorporates observations to contextualize the quantitative data on the survey (Hornik, 1984).

It is noted that time perceptions are correlated with demographics, of which, cultural difference is one of the most studied ones. It has been emphasized that such discussion on time-consumer relationship is largely limited to the Anglos context, which is certainly not representative to all cultures (Graham, 1981; Manrai & Manrai, 1995). Anglos tend to perceive time as linear, hence, time can be divided into past, present, and future, evident in the tenses in English language (Graham, 1981). Graham (1981) explains that the linear-separable perception of time allows them to associate time with money easily: in their ideology, time is wasted if it does not yield present or future values. Distinctively, there are other models, such as circular-traditional shared by Latin American societies, and procedural-traditional by American Indians (Graham, 1981). The former model originates from natural cycles and traditional agriculture lifestyle (Graham, 1981). People with this circular time perspective consider future a repeated state as the present, therefore, they enjoy the present and instant gratification without much consideration of investment on the future (Graham, 1981). The latter, procedural-traditional time perception, is embedded in cultures rich in rituals (Graham, 1981). People holding this time model do things when "time is right", but have no idea of a specific time (Graham, 1981). Different from linear-separable time model believers, people inclined to the other two rarely relate time with money (Graham, 1981). They do not "budget" time, deviating from most household economists' default assumptions on "rational" behaviours. For example, for circular-traditional model believers, it is absurd to sacrifice the present joy by saving time or money for long-term goals; same for procedural-traditional model believers to disrupt their procedures. Both ideologies are manifested in their consumption behaviours, which may seem as dissonance for researchers immersed

in linear-separable time thinking. However, the time perception one holds is not consistent in every life aspect nor it is static in every moment (Graham, 1981; Manrai & Manrai, 1995). Consumers are likely to develop a new time perspective when they integrate into a different culture (i.e., acculturation), and they "operate" cultures based on circumstances (Graham, 1981; Manrai & Manrai, 1995). The link between acculturation and time perceptions for work/ leisure is further explored in Lalita Manrai and Ajay Manrai's (1995) article. Therefore, time use researchers have been warned not to homogenize or oversimplify time perceptions into one static model (Graham, 1981; Manrai & Manrai, 1995).

During the discussion of cultures' differences on time use, "polychronicity" is a well-referenced term to describe a time use pattern. Indeed, "polychronic" (0.52% in the sampled 19 journal articles) is one of the most frequently-used words in this community, according to the NVivo query result. The term was coined by Edward Hall (1983) in his book *The Dance of Life: The Other Dimension of Time.* It describes an orientation of time use that favours doing multiple things simultaneously (Bluedorn & Denhardt, 1988). In contrast, another approach of only doing one thing at a time is called "monochronic time use" (Bluedorn & Denhardt, 1988). It can be seen as a monochronic-polychronic spectrum. Individuals are characterized by being more or less polychronic depending on their time use preferences. Kaufman, Lane, and Lindquist (1991) propose a scale called the Polychronic Attitude Index (PAI) to quantify the extent of individual-level polychronicity.

The sampled literature fail to declare a direct linkage between between individual-level polychronicity and any consumer behaviour. It is only partly explored through certain factors such as "role overload", which describes the "unbalanced" state individuals experience when they attempt to fulfill their different roles at the same time (e.g., mother, wife, employer) (Reilly, 1982). Thus, role overload becomes one common indicator of time pressure. Consumer behaviour researchers tend to link that to the consumption of convenience goods. Kaufman et al. (1991) conclude that the more polychronic individuals claim to be, the less role overload they report to feel. Meanwhile, a weak positive link is indicated between housework bearers' reported role overload and family's consumption of convenience food (Reilly, 1982). Across cultures, developing countries in general are characterized as more

polychronic than their counterparts, except Japan being a polychronic developed country (Hall, 1983). A survey-based study conducted on 956 international students in the United States indicate that when individuals originating from polychronic cultures fully integrate into the States (i.e, more monochronic), their time use behaviours also incline to the American way (Manrai & Manrai, 1995). Still, no direct predictions can be drawn solely based on polychronic/ monochronic time use preferences. However, the study does show that polychronic cultures perceive higher work hours and lower leisure hours, compared to monochronic cultures (Manrai & Manrai, 1995). This might affect time priorities of those bearing dual burdens in paid work and housework, and the shopping behaviours for convenience goods, as mentioned above.

In summary, this is a cluster of time use research from the socio-psychological perspective. Besides the attempts made to link time and human behaviours, the community also speaks about the limitations of economic literature. For example, a mixed-method approach is suggested instead of solely relying on the quantitative time use survey. Time use preferences such as polychronic time use remind time use researchers to pay close attention to secondary activities, which happen simultaneously with the main activities. The potential effects of cultural differences on time use behaviours provide insights to interpret the “dissonance” in mixed-culture societies.

Cluster 9 has a similar focus on consumer and management psychology. Although discrepancies may remain of the two communities in leading scholars and main research questions, we believe separate discussion is unnecessary for the purpose of this study.

4.3.4 Transportation

Field(s): Transportation
Discipline(s): Urban Planning

Cluster 2:

Cluster membership: 132
Median year: 2002
Sample size: 13 journal articles
Main topic(s): activity-travel modeling, travel demand analysis

Cluster 2 has 132 members and a median year of 2002 for all publications. It is a relatively young community compared to the previous ones reviewed. Journals specialized in transportation, such as *Transportation*, are the main sources for publications in this community. The sample includes 13 journal articles, 9 or which are from the journal *Transportation*. The novelty brought by this community is the introduction of spatial attributes, which complement the temporal ones for describing activity engagement.

The urban planning cluster witnessed a paradigm shift from the trip-based approach to the activity-based one (Bhat & Koppelman, 1999). The distinction between the two lays on how the central unit of analysis -- "time" is conceptualized. In the trip-based approach, time is treated as a "cost"; while in the activity-based approach, it is understood as an "all-encompassing continuous entity" (Bhat & Koppelman, 1999, p.1). Along this logic of thinking, travel is a derived demand by people to pursue activities distributed at different locations (Bhat & Koppelman, 1999; Kitamura & Sampath, 1996). Meanwhile, activity engagement is dictated by how people use their time (Kitamura & Sampath, 1996). Therefore, advocates of the activity-based approach believe that the activity-travel patterns essentially reflect on their time use (Bhat & Koppelman, 1999). Another perspective of marrying space and time is to look at them as co-existing constraints. The space-time framework (also known as the "space-time prism", a time-geographic concept) developed by Hägerstrand outlines all possibilities of "paths" for individuals on a spatial-temporal scale (Hägerstrand, 1970). Hägerstrand (1970) described his model in an explicit yet poetic language: "he (the individual whose activity-travel behaviours are modelled) cannot pass a certain point in time-space more than once, but he always has to be at some point" (p.14). The size of the prism is bound by three types of space-time constraints: capability, coupling, and authority (Hägerstrand, 1970). The capability constraints refer to those related to individual physiology (Hägerstrand, 1970). Meanwhile, human behaviours are also coupled with other people and material

artifacts (i.e., coupling constraints), as well as restricted within laws and social norms (i.e., authority constraints) (Hägerstrand, 1970). Gender rules, recognized by the sociologists, are part of the authority constraints. The size of an individual's prism rarely remains stagnant. For example, with the increased speed of transport modes, the size is expected to expand accordingly (Hägerstrand, 1970). Similarly, the use of wireless technology releases the space-time constraints to a certain degree as well (Schwanen & Kwan, 2008). This framework has been widely adopted and improved upon by Pendyala, Yamamoto, & Kitamura, 2002; Schwanen & Kwan, 2008, for example.

Researchers in this cluster are particularly interested in where the activities are conducted because changes of locations generate travel, inevitably. In this cluster, activities are classified into two types, maintenance and discretionary. The maintenance activities, such as personal care, paid work, and certain household work, are those tasks people are nevertheless obligated to perform (Kitamura & Sampath, 1996). For discretionary activities, the discreteness depends on whether or not such activity engagement adds utility to the total (Kitamura & Sampath, 1996; Yamamoto & Kitamura, 1999). The underlying utility maximization theory is consistent with the assumption in most sociological and household economic time use studies. How individuals attribute activities ranging from levels of discreteness to home or out-of-home, so called "in-home and out-of-home orientation" (Kitamura & Sampath, 1996), has been extensively studied in this community (e.g., Chen & Mokhtarian, 2006; Kitamura & Sampath, 1996; Meloni & Loddo, 2004; Yamamoto & Kitamura, 1999). This topic has been overlooked by the other time use studies, at least prior to that date (Pas & Harvey, 1991 cited in Kitamura & Sampath, 1996). Researchers in this community are intended to bridge the gap by better understanding and even forecasting the tradeoffs between mandatory and discretionary activities, as well as in-home and out-of-home orientations. For example, Chen and Mokhtarian (2006) find that if people have extra time, they are more willing to devote them to discretionary activities; meanwhile, if the travel time increases, time allocation on discretionary activities are more elastic than their maintenance counterparts. Also, there is indeed a substitution effect between the two categories of activities (Chen & Mokhtarian, 2006). Between in-home and out-of-home, 70% of the sample participants preferred to attribute more time to out-of-home

activities on working days, and to in-home on non-working days; 30% tended to choose in-home over out-of-home during either time periods (Yamamoto & Kitamura, 1999). Another interesting academic interest we noticed is the relationship between space-time constraints and the Information and Communication Technologies (ICTs). How do ICTs modify the space-time constraints in this information age? Built upon Hägerstrand's space-time prism, Schwanen and Kwan (2008) find that the accessibility of phones free people to some extent from some spatial and temporal fixed activities. However, phone-use might reinforce the household gender roles by, for example, imposing childcare responsibilities to moms who are not physically present (Schwanen & Kwan, 2008).

In summary, this cluster sheds some new light on time use research. Activity-based approaches place more importance on the time dimension and utilize time use data to predict travel behaviours. Bhat and Koppelman (1999) did a literature review on how time use research is integrated in the activity-travel modeling. Based on studies to that date, they suggest to develop a comprehensive theoretical framework for time use research adopting a multidisciplinary approach (Bhat & Koppelman, 1999). In our perspective, economists and sociologists can contribute to building up a model incorporating individual/household socio-economic characteristics to predict the length and location of the conducting of such activities; psychologists are able to provide contextual information and explain some dissonance; planning scholars can utilize tools such as Geographic Information System (GIS) to add the spatial dimension. Such a project requires a lot of cross-disciplinary collaboration, and doubt exists to what extent the final product can be practical instead of purely theoretical.

4.4 Manual testing results

Recent decades have witnessed the development of socio-ecological thinking of human time. Despite the appearance of several articles, for example, Ringhofer (2014)[33] and Ringhofer (2015)[34], there is minimal representation of time use

[33] The four time-relevant subsystems of the social system (Ringhofer, 2014)
[34] Time, labour, and the household: measuring "time poverty" through a gender lens (Ringhofer, 2015)

research in the discourses of sustainability in our co-citation network. The largest 10 communities of co-cited documents reveal little about such research interests. We are curious about what their knowledge bases are, where the socio-ecological conceptualization of human time emerges from, and how they diverge from *traditional* time use studies. With these questions in mind, we conducted a micro-scale manual testing for five articles we are familiar with[35].

Among the 196 cited references we deemed as part of the knowledge base for sustainability time use studies, 73 (37%) are covered in our pool of co-cited documents. 37 (19% of the total) have the exact titles captured and the rest 36 (18% of the total) are captured by publications under the same first authors (See *Fig. 8*). For example, the article “Time use survey data in a decomposition analysis” in the Journal of Industrial Ecology (Jalas, 2008) is not captured, but two of Jalas’s other articles , published in 2002 and 2005, respectively, are in the pool. Regarding the 123 documents (63%) are not captured, 20 of them (16% of the not captured, 10% of the total) are neither indexed nor cited by any indexed documents in Scopus.

35 We added Wiedemhofer et al (2018) when conducting content-similarity analysis of the abstracts.

Figure 8. A breakdown of the 196 documents according to their appearance in co-cited document pool and in Scopus

I further investigated which co-citation cluster(s) the captured 37 articles fell under. As expected, cluster 0 made the most appearances (24) for these references, followed by cluster 3 and 9 (both 6 frequencies), then 1, 4, 10, and 14 (all 3) (See *Appendix D*). Against the theme labels we already had, household economics, well-being, and the sexual division of labour (childcare) are the major themes of the communities they belong to.

To expand the scale of the manual testing, we performed a search with a list of sustainability-related keywords on *title, abstract,* and *keyword* of all the source articles (see Table 8 for findings). It is noted that containing such keywords may suggest the article being part of the sustainability time-use research, but does not guarantee so. For example, some of the articles triggered by the keyword search of "land", in fact have mentioned Nether*land* and/or New Zea*land* in their abstracts, with minimal linkage to land-time use budget in sustainability. However, we also found some highly relevant work, such as "Sociometabolic transitions in subsistence

communities: Boserup revisited in four comparative case studies" (Fischer-Kowalski, 2011), "Examination of relationships between urban form, household activities, and time allocation in the Atlanta Metropolitan Region" (Lee, Washington, & Frank, 2009), "The role of women in aquaculture in the Philippines: obstacles and future options" (Felsing & Baticados, 2001). Curious about whether they formed into cluster(s) or were still scattered in the co-citation network, we highlighted the nodes (each represents an article) that contain the keywords of interest in our co-citation network (see *Fig. 9*). The graph shows that the articles touching on sustainability spread all over the network without any obvious clustering.

Table 8

Sustainability keywords and their frequencies

Keyword(s)	Frequency
land	59
energy	51
environmental	36
sustainable	13
sustainability	6
socioecological	1
social ecology, socio-ecological, sociometabolic, ecological economics, industrial ecology, material and energy use, labour intensity, land-time budget	0

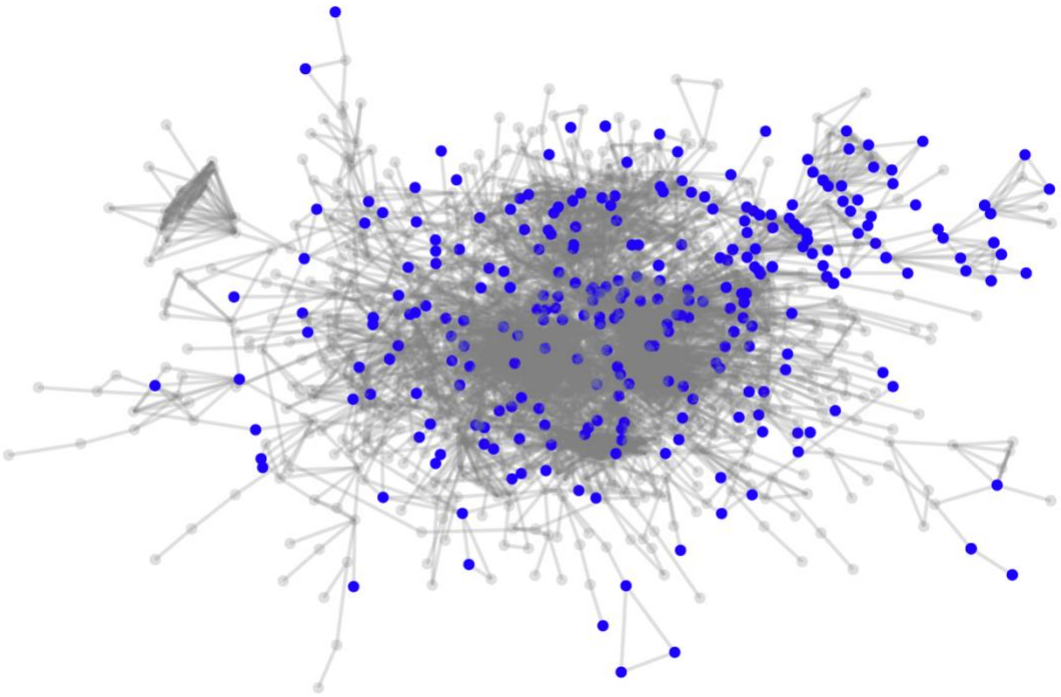

Figure 9. Co-citation network with highlighted (potentially) sustainability articles

4.5 Content-similarity network: detecting the sustainability theme

Having recognized the sustainability cluster being underrepresented in the co-citation map, we triangulated our method by generating a content-similarity network from the abstracts. The abstracts consist of those from the original dataset, the relevant references of the five articles in the table, and the relevant references of the one recent published review article by Wiedemhofer et al (2018).

The content-similarity network, which we labelled in the same methodology as we did previously (see Table 9), showed overlapping themes in child care (e.g., #46), sexual division of labour (e.g., #7), and schools of thoughts falling under household economics (see Table 9). Instead of attempting to differentiate the clusters on the same themes between the two networks, we focused on the new light shed by the content-similarity network, namely community #18 (highlighted), which research perspectives have not been captured in the co-citation network.

Table 9

Overview of the largest 10 communities in the content-similarity network

Community	Member	Theme label(s)
46	114	Child care
32	60	Child care
93	50	Physician visit time
180	48	Sleep
7	37	Sexual division of labour
110	37	Housework time
18	35	Household energy use
49	35	Students' time use
12	31	Transportation, travel
171	29	Child care

Community 18 in our similarity network featured a collection of 35 articles, 13 of which have a shared research method, commonly referred to as "time use cluster analysis"; while the rest (23, one overlapped) look closely into the relationships between time use and energy use. The following section summarizes the research objectives, key methods and databases, as well as findings and implications for this similarity network. We focus primarily on the theme of energy-related behaviours to explore the underlying sustainability indications.

Content-similarity community 18
Community membership: 35
Median year: 2013
Main topic(s): time use cluster analysis, energy use

With 35 journal articles in this cluster, the most mentioned word (3.12%) in their abstracts is energy, followed by time (2.62%), activity (2.62%), household (2.29%), and cluster (1.69%)[36]. We coded the 35 abstracts into four categories, theories (or conceptual framework), research question(s), methods and databases, as well as findings, accordingly.

This community can be further divided into two subsets: 13 journal articles share the similar method called “time use cluster analysis”; 23 (one overlapped with the former) have a convergent theme on energy-related behaviours.

4.5.1 Time use cluster analysis subset

Time use cluster analysis is a type of data mining that attributes the time use data into “clusters” and cross-compares them against different variables (Ferrar, Olds, Maher, & Maddison, 2013). In this context, members within each cluster have a similar time use pattern distinctive to other clusters’. However, it should not be confused with the reference of “clusters” in our citation and similarity networks, which deal with time use research documents not time use data directly. Content-wise, the majority of the 13 journal articles share a similar focus on the health-related quality of life and the demographics of the youth (e.g., Casey et al., 2016; Ferrar, Olds, Maher, & Maddison, 2013; Ferrar, Olds, & Maher, 2013; Ferrar & Golley, 2015; Wong et al., 2017). For example, Ferrar and her colleagues conducted sex-specific cluster analyses in their New Zealand adolescence and Australian youth time use studies, both published in 2013. In both studies, they discovered three clusters for each gender, characterized by varying social interaction, team sports, screen time, study time, etc (Ferrar, Olds, Maher, & Maddison, 2013; Ferrar, Olds, & Maher, 2013). When taking the socio-demographics and weight status into the equation, time use clusters of boys from the 10-16 year-old New Zealand samples were found associated with ethnicity while the ones of boys from the 9-16 year-old Australia sample were correlated with age, pedometer steps, and remoteness; for girls, both studies reveal a correlation of serves of “extra foods” with the New Zealand study

[36] Including their word variants

indicates association with weight status, and Australia study suggests a link to “fat and fruit intakes” (Ferrar, Olds, Maher, & Maddison, 2013; Ferrar, Olds, & Maher, 2013). These types of studies have great implications for policy-making in the health and well-being arena. There are, however, some outliers not falling under the health-related and youth-focused category. One particular article titled “a cluster analysis of energy-consuming activities in everyday life” groups individuals based on similar timings and durations in terms of performing electricity-demanded activities (Palm, Ellegård, & Hellgren, 2018). Aligned with the research design of other time use cluster analyses, this study realizes the potential implications behind certain activity patterns and performs the “clustering” based on the recognized patterns of time use sequences rather than the socio-economic and demographic variables (Palm et al., 2018). By doing so, they portrayed activity-based profiles, which might help explore how flexible certain energy-consuming activities, such as cooking, doing laundry, and watching television, are to be rescheduled (Palm et al., 2018). Noticeably, this study adapts the Hägerstrand’s (1970) time-geographic conceptual framework, where capability, coupling, and authority constraints are present to affect individual activities. We briefly mentioned it in the discussion of urban planning community, but will go into details in the energy-focused section below.

4.5.2 Energy-intensive lifestyle and the conceptual framework

Recent decades have witnessed people’s attempts of transitioning to a less energy-intensive and lower-carbon lifestyles. Time, among other socio-economic constraints, dictate energy-consuming activities. However, unlike the monetary budget, daily time allocation has to be aggregated to 24 hours, which means a time increase dedicated to one activity leads to a decrease in the rest of the activities on that day (De Lauretis, Ghersi, & Cayla, 2017; Jalas, 2005; Jalas & Juntunen, 2015). Therefore, time use approach becomes complementary to the study of household energy demand. Indeed, the association of household energy use and time use is slowly gaining traction in the ecological economics and industrial ecology communities, evident in our sampled twenty-three articles in this subgroup. Nevertheless, it is an emerging focus area that can benefit from the knowledge contribution made by household economics, sociology, psychology, and urban

planning disciplines. The purpose of discussing this household energy use subset is two-fold: first, this body of literature explores the possibility of approaching environmental issues from a time use perspective, the empirical findings of which can be applied in future policy-making; second, we seek to use this subset as a case study to understand the transcending disciplinary boundaries in time use research knowledge base. For the latter purpose, we built a conceptual framework (see *Fig. 9*) to describe the key factors conditioning the household energy-consuming activities, and identify the underlying fields that have been or can potentially be borrowed.

Energy consumption and policies have accumulated an extensive body of literature outside of the time use research world. However, this subset of literature finds it problematic that individual energy-related behaviours within a household remain unknown (Ellegård & Palm, 2015; Löfström & Palm, 2010). At a micro-level, an empirical gap lies where household energy consumption is calculated in an aggregate notion, the complexity of activity division and sharing among household members is undermined (Isaksson & Ellegård, 2015). Therefore, energy policies are not effectively tailored to inform real-life behavioral changes. To open this "blackbox", a software named "VISUAL-TimePAcTS/energy use" is used to track the daily energy-related activity sequences (Ellegård & Palm, 2011; Ellegård & Palm, 2015; Löfström & Palm, 2010). For example, according to the visualization of a set of Sweden time diaries during the software development stage, women in the sample spent more time at home and used more electricity for cooking than men did (Ellegård & Palm, 2011). Admittedly, the results may vary across populations and the dataset used to demonstrate the software is quite dated (from a pilot study conducted by Statistics Sweden in 1996). However, their argument in the often mismatch of whom the energy conservation campaign is delivered to (household head registered with the energy company) and who is in charge of the majority of household energy consumption, still stands.

To take it one step further, some of the activities require teamwork among household members. Isaksson and Ellegård (2015) conceptualized it in two principles: project division and project sharing. Regarding meal provision as a household project, grocery shopping, storing food, prepping meals, and washing dishes are a sequence of activities involved in the project (Isaksson & Ellegård, 2015). Indeed, meal

provision (meal preparation and cleaning up) is among the highest direct energy-intensive household projects because it requires cooking and water-heating energy in addition to base residential energy and appliance energy use (De Lauretis, Ghersi, & Cayla, 2017, p.639). In contrast, “eating out” is an activity fulfilling similar feeding needs but with a lower energy intensity (De Lauretis et al., 2017). Project division, in the meal provision scenario, means either one adult performs all relevant activities or all adults perform all activities separately and for their own feeding needs (De Lauretis et al., 2017). Project sharing can be translated to three cases: 1. Household members cooperate in activities (e.g., wash dishes together); 2. All adults engage in their specialized activities of the meal provision (e.g., one person prepares food, and another one washes dishes); 3. All adults perform all activities on their scheduled day (e.g., one person is responsible for providing meals on a given day) (De Lauretis et al., 2017). Consistent with earlier literature (e.g., Ellegård & Palm, 2011), De Lauretis et al. (2017) find women are doing more household work and their schedule is more fragmented. They suggest cooperation with other household members as a strategy to not only avoiding resource overconsumption and time pressure, but also increasing the enjoyment of household chores, and therefore people’s well-being (De Lauretis et al., 2017). The process utility of certain household work is otherwise overlooked in the traditional camp of household economics. In reality, the division of work and leisure is not clear-cut. Can chores like cooking and washing dishes become a form of leisure activities that bond household members? It requires more consideration of the psychological side of time allocation.

At a macro-level, household energy consumption and its induced GHG emissions, both direct and indirect, are greatly impacted by urban forms in regards to housing types, transportation, and availability of different goods and services (Heinonen et al., 2013; Jalas, 2005). Consistent with Hägerstrand’s (1970) time-geographic approach to everyday life, the time use under the effect of urban forms is described as a “situated lifestyle” by Heinonen et al. (2013). Admittedly, the increase of urbanization levels is linked to a decrease in direct GHG emissions (Heinonen et al., 2013). However, when accounting indirect emissions associated with the consumption of goods and services, it shows more urbanized areas are leading a more energy- and carbon-intense lifestyle, offsetting the reduced energy and

material use in shared services (Heinonen et al., 2013). The urbanized lifestyle is characterized by more purchase in clothes and electronics, and even creates needs for a second home and/or a summer cottage (Heinonen et al., 2013). In a decomposition study, Jalas (2005) indicates the time use pattern is overall shifting to a lower energy-intensive profile while an increase in housework time use intensity is still evident. Part of the reason is the time use does not increase proportionately to the household size, in the same manner as energy use (Jalas, 2005). In his later publication (2008), he suggests there might be time use rebound effects in presence, as well, where individuals delegate tasks to an energy-efficient service source while engaging in a higher energy-demanding activity with their saved time budget. Similarly, Yang and Timmermans (2017) view energy-consumption activities in a systematic way by conceptualizing long-term conservation as a portfolio choice problem among options such as switching to energy-efficient vehicles, and/or adopting solar panels in house, etc.

Indeed, how are our energy use, GHG emissions, and environmental impacts in general conditioned by the time-geographic constraints? What constitute the "situated lifestyle"? At a conceptual level, borrowing the stocks and flows model in industrial ecology and applying it with the household economics lens, Jalas (2005) describes "consumption" of goods and services as "a set of *temporal* activities in which consumers utilize or engage with the various products of industrial systems and through which resource flows pass… accordingly, resource flows enable the various ways in which consumers desire or come to spend their time" (Jalas, 2005, p.132). Jalas and Juntunen (2015) continues to explore the disciplinary base of time use research, and if it is compatible to ecological economics. They suggest ecological economists remain critical towards the "instrumentalization" and "rationalization" (e.g., the strict distinction between labour and leisure) within the household economics' camp. However, acknowledging the growing body of the time use research, they point out the absence of an explicit theorization of "time use" that also highlights the "human agency" (Jalas & Juntunen, 2015). Admittedly, there are scholars in the intersection of ecological economics and well-being studies exploring the relationship between subjective well-being and household environmental impacts. For example, one of the 35 articles in this community, titled "An Exploration of the Relationship between Socioeconomic and Well-Being Variables and

Household Greenhouse Gas Emissions", found no correlation between GHG emissions and degrees of well-being at an urban level (Wilson, Tyedmers, & Spinney, 2013). In other words, subjective well-being is not reliant on certain lifestyles that may induce more environmental impacts (Wilson et al., 2013). When pairing GHG emissions and self-reported time stress index scores, Wilson et al. (2013) did not find any clear relationship between the two. However, this area of research has not been fully explored, nor have the scholars on similar topics achieved a consensus on the linkages between well-being and environmental impacts.

In an attempt to address this research gap, we constructed a conceptual framework (see *Fig. 10*) to explain household energy-related consumption behaviours based on some of the contributing knowledge base we found in the networks. While we took primarily the consumption-based approach, we also acknowledged the complex system features, such as system interactions and the human agency (see Baynes & Wiedmann, 2012 for their systems model).

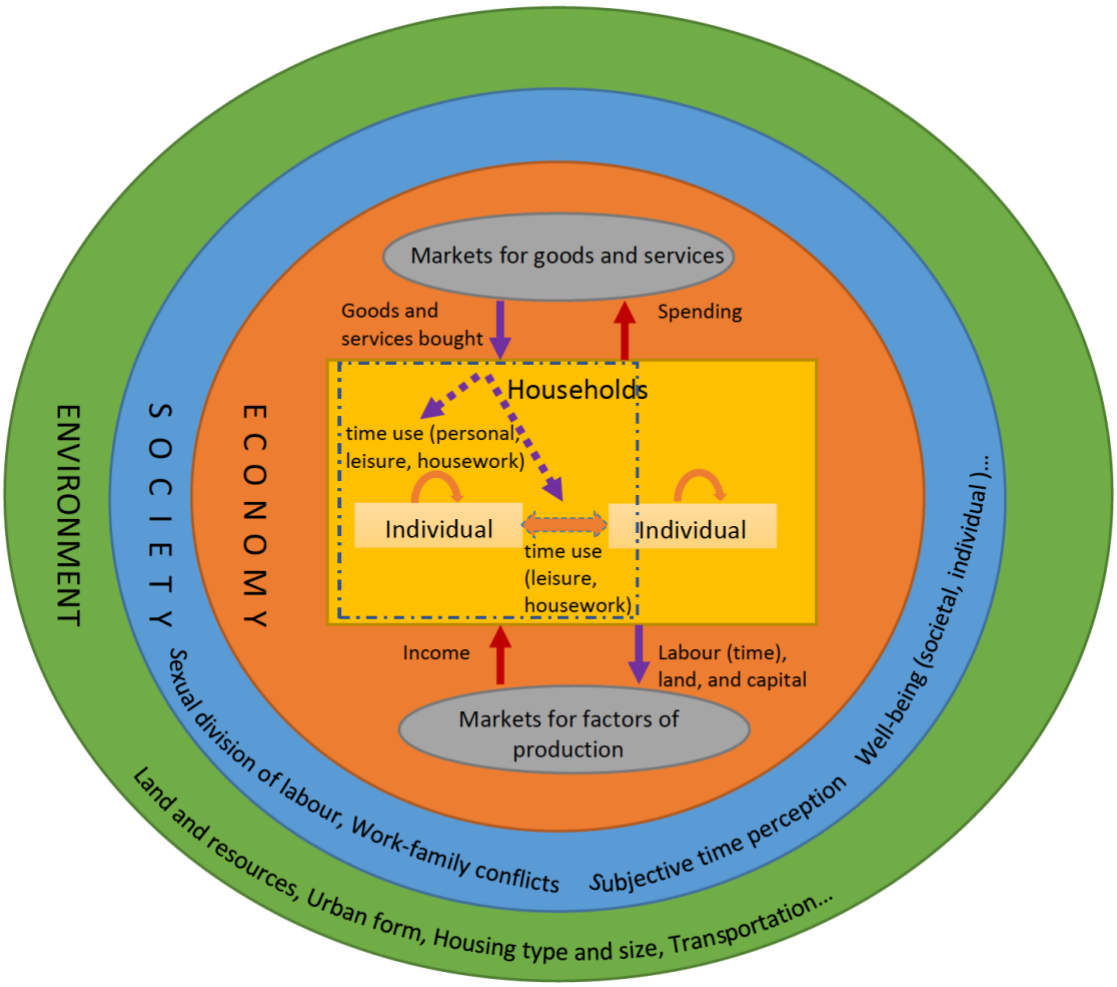

Figure 10. Conceptual framework

We built our framework upon the three-pillar sustainability model (environment, society, and economy). In the inner circle, we depicted the market system featuring the household as our unit of analysis. In addition to the inflows and outflows of exchanges with the markets, the household itself also serves as a “mini-firm” of production that combines time use with purchased goods and services (Becker, 1965). Despite Becker’s theory dominates the household economics, the main criticism the original work (1965) receives is the lack of consideration of the division of labor within households. At a disaggregated level, individuals in a household of more than one person may divide and/or share their energy-consuming activities. We mentioned the meal provision as an example in the above section. Although Becker addressed the theory of “specialization” in his later paper (1985), sociologists and demographers have introduced the gender lens to contest the oversimplified household economic model, and added some discussion from a household

composition point of view. Despite that, individuals exhibit different time use patterns (polychronic-monochronic orientations) and different cultures embody “time” in various manners (e.g., the “clock time” notion is not universally embraced), which perspectives challenge the instrumentalism and rationalization of Becker’s model. Besides the tangible products, time use also impacts individual and societal well-being through “process benefits” and the “evaluation of the state of the world” (Juster et al., 1985). We allocated the three fields of studies to the outer circle -- “society”. In the concentric-ringed sustainability construct, environment is the ultimate limit setting the boundaries. Individual activities are bound by the space-time constraints (Hägerstrand, 1970). In this case, household energy-related activities are greatly conditioned by urban forms, which affect housing type and transportation (Heinonen et al., 2013). Beyond that, it creates a “situated lifestyle” that in turn modifies the consumption of goods and services (Heinonen et al., 2013). As a result, household energy-related behaviors can be linked to the environmental impacts (e.g., GHG emissions, land use change) and even the anthropogenic climate change. From a systematic perspective, the trade-offs in time use between labour and household work have potential implications in not only our well-being, but also our energy and resource use. There has been a stream of research on whether the reduction of labour time will promote a sustainable economy and lifestyle (e.g., Buhl & Acosta, 2016; Nässén & Larsson, 2015; Shao & Shen, 2017), and in this scenario whether a rebound effect is in presence (e.g., Jalas, 2008). We hoped our conceptual framework reflects the multifaceted nature of household energy consumption from a time use perspective.

5. Conclusions

Time use research has been evolving organically as a field since the mid-1960s when large-scale datasets were made accessible by multinational projects (e.g., Szalai, 1972). Household economists (e.g., Cluster 0), sociologists (e.g., Cluster 1), psychologists (e.g., Cluster 4), urban planning scholars (e.g., Cluster 2), etc., have been actively involved in building the knowledge base of this field. Literature reviews, such as “A Retrospective and Prospective Survey of Time-Use Research” (Bhat & Koppelman, 1999), attempt to define the field from a perspective of their own speciality. In contrast, science mapping is a more holistic approach to gain a “bird’s eye view” of the time use research. Our paper thus bridges the gap by combining the Document-level Co-citation Analysis (DCA), and qualitative scoping review: tracing the intellectual structure, on the one hand; and contextualize it with a more in-depth review, on the other. We also triangulated the DCA by exploring the content-similarity analysis derived from the cosine similarity. In spite of our effort on presenting the breadths and depths of this field, this study is limited at both data collection and analysis levels. This chapter is organized as follows: section 5.1 discloses the study limitations, under which 5.1.1 lists those on the data collection stage and 5.1.2 on the data analysis; section 5.2 concludes the implications and recommendations for future work.

5.1 Study limitations

To answer our first set of research questions, “how has the time use research field evolved over time? And what are the most influential journals, authors, and documents in the field of time use research?”, we conducted the document-level co-citation analysis on the 3063 Scopus records we deemed as research front of the field. With the help of *metaknowledge* and Gephi, we were able to analyze and visualize the co-citation network. However, it remains as a major concern to what extent the network accurately represents the specialities underpinning the time-use research field. According to our scoping review results, three kinds of errors are evident: 1) different specialties being falsely merged; 2) same speciality being

separated; 3) specialit(ies) that exist(s) in the real academic world disappearing from the network. These errors, particularly the last one, created difficulty for us to fully investigate on the current state of sustainability topics in the field. In the following two sections, we discussed how these errors were made possible by the study limitations, and how they affected the results' interpretation .

5.1.1 Data collection limitations

The goal of data collection was to find an exhaustive list of documents that are also representative to the time use field. Then, the intellectual structure of the field will reveal itself based on the co-citation relationship of the references being cited by these research front. Therefore, the scope and quality of the documents we retrieved from Scopus dictate the subsequent analysis. Three factors may contribute to the limitations in data: the scope and coverage of Scopus, our keyword search strategies, and data refinement practice.

Although Scopus is claimed to be superior to Web of Science (WoS) in terms of journal coverage (Scopus's journal coverage is 1.5 times the WoS's), as well as more rigorous in its selection and indexing than Google Scholar (Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016), it is still far from perfect to offer a representative sample for the time-use field. The time use documents we extracted from Scopus can only be traced back to the year of 1963 (see *Fig. 4*), which is inconsistent with the real timeline for historical time use literature having been documented since the early 1900s. In fact, the former Soviet Union, the United Kingdom and the United States pioneered in conducting some time use studies before World War II (Niemi, 1995 cited in Fleming & Spellerberg, 1999; Harvey & Pentland, 1999). Besides that, according to our manual testing results, 20 (10%) of the 196 references we deemed as part of the sustainability knowledge base for the field, were neither indexed nor cited by any indexed documents in Scopus. The reasons behind these inconsistencies can be two-fold. Firstly, historical time use research might be neglected because Scopus's records are quite limited for those published prior to 1995 (Falagas et al., 2008). Admittedly, Scopus's metadata indicates that its oldest record can be dated back to 1788, and it has made an effort

to add over 195 million pre-1996 cited references to the database (Scopus, 2017). It is still quite possible for certain documents, especially if not well-cited, missing from the database. As a result, the starting year for the field based on our data retrieval might be later than the actual one. The missing cited references can be among those that failed to be included in the database, even though the following explanation seems more plausible for this one. Secondly, it is well-acknowledged that Social Sciences and Humanities are underrepresented compared to their counterparts such as Engineering and Life Sciences (Harzing & Alakangas, 2016; Mongeon & Paul-Hus, 2016). It remains unknown to what extent the lack of document records from Social Sciences and Humanities contributes to the disappearance of the sustainability time use specialities. However, it is convincing to assume the two are correlated.

Besides the limited scope and coverage of Scopus, our keyword search strategies cannot guarantee to have retrieved the most accurate data as well. We used the generic word combinations ,“time use” and “time diary”, as the references to the method commonly used in the field. We performed the search in title, abstract, and keywords for journal articles. By no means, the keywords we used were able to return all relevant articles in the field; and more importantly, the search string returned a lot of “noise”, as expected. Having included these irrelevant articles would be problematic for the following analysis. We filtered out 1435 mis-captured ones using Excel’s conditional formatting feature. Although we have been meticulous about the search and refinement steps, there must still have been articles overlooked as well as “noise” undetected. It might be an issue for the analysis of the research front because of the false inclusion. However, we assume the errors it made could be negligible for co-citation analysis. The mis-captured articles rarely share similarities in content. Therefore, it is very less likely for their cited references to form into new clusters.

5.1.2 Data analysis limitations

Co-citation analysis is built upon the assumption that articles being co-cited share certain degrees of similarity. However, Leydesdorff (1998) indicates that the reasons behind a citation may vary. Without contextual information, it is difficult to interpret the co-citation strengths based on their numeric values. One document can be cited simply for criticism purpose, while co-citation relationship can still be formed with another one even though they can represent diverse schools of thoughts or focus on different subject matters. The lack of context might lead to error 1 discussed above, where different specialties being falsely linked up. The fragmentation and isolation (error 2), however, might be solved by adjusting the edge weight threshold. It takes trial and error before a relatively-accurate co-citation network being created.

We were mostly curious about why the very limited numbers of captured sustainability literature do not form into communities (error 3). In the previous section, we discussed how Scopus's coverage may contribute to it. In fact, 10% of the 196 documents are not indexed in Scopus. However, two questions remain: 1) why there were 103 documents that were not in our pool of co-cited documents but indexed in Scopus, meaning they had a fair chance to be captured? 2) Why are the 73 covered in the network scattered over different communities rather than clustered up? Our assumptions are either there is generally a lack of similarity (co-citation relationships) among these documents, or it takes time for citations to accumulate and co-citation relationship to form. In other words, time use research has not relied much on the knowledge base of sustainability studies yet. The sustainability keyword search results (see *Fig. 9*) confirm that the scattering is not limited to those 73 articles. Even with a shifted focus on the abstracts to avoid the citation biases, we were only able to detect the energy-time use cluster, which is a subgroup of sustainability time-use research. According to the literature review, a whole set of socioecological studies are neglected.

Another limitation lays under the qualitative nature of the scoping review. For the purpose of finding out the common themes effectively, we sampled the top 10% of the documents with the highest degree centrality scores to represent the cluster in question. It is questionable whether or not the top 10% are sufficient enough for

detecting the common themes. Even if so, part of the sampled documents are books, which we were not able to look closely into. Additionally, I have to acknowledge that I am not trained by any particular field I performed the reviews on. Therefore, the reviews do not hold any critiques or quality judgement rather than thematic summaries.

5.2 Implications and future work

This is a novel study that maps the field of time use research with a unique combination of co-citation analysis, content-similarity analysis on abstracts, and qualitative scoping review. At the method level, we made our effort to advance bibliometric studies and address some of the limitations of co-citation analysis. At the conceptual level, this is the first attempt to gain the holistic view of the time use field, and more importantly, explore the intertwined roots between sustainability and time use. Consistent with what we found from the literature review, time use data has the potential to aid the understanding of the social and behavioural side of sustainability (Gross, 1984; Jalas & Juntunen, 2015; Minx & Baiocchi, 2008). Taking a time use approach to sustainability studies complements the conception of human-environment interactions outside the economic system, where monetary data and physical data sometimes fail to describe. Although we did not find explicit evidence of sustainability literature, particularly the ones with exclusive focus on the biophysical resources, in our networks. The social aspects of sustainability, including discussion on human well-being and gender equality, are embedded in the time use research. Sustainability scholars can deepen their understanding of the relationship between time use and environmental impacts from leisure/ quality of life, consumer behavioural, and gender studies. For instance, from a systematic perspective, Juster et al. (1985) suggest to look beyond the tangible outputs from time use, and acknowledge the “process benefits” and the “evaluation of the state of the world”. Such theorization is helpful for the sustainability scholars to understand the intangible and subjective outcomes (e.g., attitudes, values, emotions) from certain activities. Regarding the future of work, the discussion has been emerging on whether working time reduction will promote sustainable consumption, facilitate the

pursuit of degrowth, and become an ultimate solution to climate change (see e.g., King & van den Bergh, 2017). Topics surrounding sustainable work and work-sharing are gaining momentum in the ecological economics (see e.g., Zwickl, Disslbacher, & Stagl, 2016). We believe concepts and findings we identified from fundamental time use studies will help sustainability scholars redefine “work” in a degrowth society.

For future research, we have three recommendations. First, science mapping of the field should be a longitudinal work. As suggested in the literature review and study limitations, the accumulation of citations requires time. Hence, it is critical for such research to be carried out in hope to understand the growth of the knowledge base in the field. We are curious if the relative young age of the sustainability discourse in fact results in the underrepresentation in the co-citation network. We also suggest researchers who are interested in the field set up the keyword alert in Scopus, and monitor the advances in research front. Second, concerning the time use data playing a major role in the field, we are looking forward to future studies making datasets as the unit of analysis. For example, one can make a list of how one particular dataset being used in different projects, and see if there are potential interdisciplinary collaboration opportunities based on the shared data. Finally, we urge a thorough theorization of “time” with emphasis on human agency, combining the schools of thoughts from different disciplines. Such work will help add the social and behavioural aspects to the quantitative sustainability research. This thesis explored the link between time and energy use from the consumption-based approach. We noticed that the social metabolism theory proposed by the social ecologists have not received enough attention (at least according to citation data) yet. We believe their work in this regard can benefit from the intellectual foundations we identified, and the future research can build upon a complex system model. A great way to start is to use our co-citation map (see *Fig 7*.) as a tool and focus on the publications with high eigenvector and betweenness centralities (see Table 7).

In conclusion, sustainability scholars stand at the interface of economic, social, and environmental research. According to our findings, there has been robust insights on how time allocation informs the social aspect of sustainability, such as non-market activities, individual and society well-being, as well as urban planning. Due to the limitations in bibliometric analysis, we found a steadily growing group of literature on

socio-metabolic studies and land-time budget have not surfaced as a cluster in our network maps. The finding in itself provides interesting implications for both information science scholars from a case study standpoint, and sustainability scholars from a citation practice perspective. We would like to reinforce the message that scientific fields should not operate as silos, and synergies can be created with knowledge integration. To carry forward, we believe a thorough theorization of “time” drawn from multiple disciplines will benefit the advancement in sustainability time-use research.

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Zhao, D., & Strotmann, A. (2015). *Analysis and visualization of citation networks*. San Rafael: Morgan & Claypool.

Zwickl, K., Disslbacher, F., & Stagl, S. (2016). Work-sharing for a sustainable economy. *Ecological Economics*, *121*(Complete), 246–253. https://doi.org/10.1016/j.ecolecon.2015.06.009

Appendices

Appendix A

"Noise" keywords frequency table

Retrieved keywords	Frequency
time, use time, use time. Use time; use Time: Use time. Use time. Uses time) use time). Use times-Use times use times, uses times; use times: Uses times. Use Times's Use Times": Use	78
first time use first time uses first time, use first-time use	30
real time use real time uses real time) uses real-time use real-time uses real-time' use	28
same time use same time uses same-time use	8
full-time use full time use	7
one time use one-time use	6
long time use long-time use	5
life time use life-time use	3
part time use part-time use part-time-use	3
night time use night-time use	2

time: diary Time. Diary	2
cross time use cross-time uses	1
prime time use prime-time use	1
short time use short-time use	1
single time use single-time use	1
[Extensional search term] first-time-use real-time-use same-time-use full-time-use one-time-use long-time-use life-time-use part-time-use night-time-use cross-time-use prime-time-use short-time-use single-time-use	0
[Additional notes for irrelevant journals] Serie Zoologia Biological Conservation Journal of Ornithology Ornis Fennica Functional Ecology Applied Animal Behaviour Science Zoo Biology Experimental Animals	8

Appendix B

Python scripts (credited to John McLevey)

Research front analysis

```
import metaknowledge as mk
import pandas as pd
import networkx as nx
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
```

```
RC = mk.RecordCollection('data/final_scopus', cached=True)
```

```
Out[5]: 3063
```

```
growth = pd.DataFrame(RC.timeSeries('year', outputFile = 'data/cleaned/growth.csv'))
```

```
print(RC.glimpse())
```

Co-citation network analysis

```
net = RC.networkCoCitation(coreOnly = False)
len(net.nodes())
len(net.edges())
```

```
mk.dropEdges(net, minWeight=3, dropSelfLoops=True)
mk.dropNodesByDegree(net, minDegree=1)
print(mk.graphStats(net))
```

```
import community
partition = community.best_partition(net)
modularity = community.modularity(partition, net)
print("Modularity: " + str(modularity))
```

```
degree = nx.degree_centrality(net)
eigenvector = nx.eigenvector_centrality(net)
betweeness = nx.betweenness_centrality(net)
```

```
centcom = pd.DataFrame.from_dict([betweeness, eigenvector, degree, partition])
centcom = pd.DataFrame.transpose(centcom)
centcom.columns = ['betweenness', 'eigenvector', 'degree', 'partition']
centcom.sort_values('betweenness', ascending = False)[:10]
```

```
sns.pairplot(centcom, hue = 'partition')
plt.savefig('figs/centrality_scatterplot_matrix_w_communities.pdf')
```

```
nx.draw_spring(net, node_color = colors, with_labels = True, font_size = 2,
               cmap=plt.cm.Accent, node_size = 33, edge_color = "#D4D5CE", alpha = .95)
plt.savefig('figs/cocite_articles_labeled.pdf')
```

```
nx.write_graphml(giant, 'data/cleaned/giant_document_level.graphml')
```

Content-similarity network analysis

```
from sklearn.feature_extraction.text import TfidfVectorizer, CountVectorizer
from sklearn.metrics.pairwise import cosine_similarity
import networkx as nx
import pandas as pd
import numpy as np
import community

def construct_simnet(text_data, sim_threshold = .5): # drop_isolates = False
    """
    Takes in a text data in list format, returns a networkx graph where documents
    Are connected based on cosine similarity. Default threshold is .5
    """
    vectorizer = TfidfVectorizer(stop_words='english', max_df=0.3, min_df=10,
max_features=3000, norm='l2')
    matrix = vectorizer.fit_transform(text_data)
    sim = cosine_similarity(matrix)
    adj_mat = pd.DataFrame(np.round(sim, 2))
    # set baseline sim threshold
    for col in adj_mat.columns:
        adj_mat[col][adj_mat[col] < sim_threshold] = 0
    for col in adj_mat.columns:
        adj_mat[col][adj_mat[col] == 1] = 0

    G = nx.from_pandas_adjacency(adj_mat)
    print(nx.info(G))
    # get text data to add as attribute
    d = dict(enumerate(text_data)) # dict with node id as key and original text as value
    nx.set_node_attributes(G, values = d, name = 'Text')
    return G


def text_as_node_attribute(network, text_data):
    """
    Takes in a list of texts (e.g. same as used in `construct_simnet`) and
    adds them to the network object as a node attribute. Must be the same len
    (i.e. don't delete isolates from the graph before doing this), and if using
    a differnet text list then the one used to create the network in teh first place,
    the index positions for the list must be the same as the one used to construct
    the network. Otherwise they will not get assigned to the right nodes.
    """
    d = dict(enumerate(text_data)) # dict with node id as key and original text as value
    nx.set_node_attributes(network, values = d, name = 'Text')
    print('Text data added as node attribute.')
    df = pd.DataFrame.from_dict(d, orient='index', columns = ['Text'])
    df['Node'] = df.index
    df['Node'] = df['Node'].apply(str)
    return df
```

```
def get_communities_df(network, print_sizes = True):
    """
    Returns a dataframe with nodes and community membership.
    Adds membership data to the network object.
    """
    partition = community.best_partition(network)
    # add it to the networkx object
    nx.set_node_attributes(network, values = partition, name = 'Community')
    num_coms = float(len(set(partition.values())))
    modularity = community.modularity(partition, network)
    print("Modularity: {}\nNumber of Communities: {}".format(modularity, num_coms))
    colors = [partition[n] for n in network.nodes()]
    # construct df
    coms = pd.DataFrame.from_dict(partition, orient = 'index', columns = ['Modularity
Class'])
    coms['Modularity Class'] = coms['Modularity Class'].apply(str)
    coms['Node'] = coms.index
    coms['Node'] = coms['Node'].apply(str)
    com_sizes = coms.groupby('Modularity
Class').size().sort_values(ascending=False)
    if print_sizes == True:
        print(com_sizes)
        return coms
    else:
        return coms

def compute_centralities(network):
    """
    Computes common centrality measures for the network, adds the scores to the
    network object, and returns a dataframe with the centrality scores.
    """
    d = nx.degree_centrality(network)
    nx.set_node_attributes(network, values = d, name = 'degree')

    e = nx.eigenvector_centrality(network)
    nx.set_node_attributes(network, values = e, name = 'eigenvector')

    b = nx.betweenness_centrality(network, normalized = True)
    nx.set_node_attributes(network, values = b, name = 'betweenness')

    df = pd.DataFrame([d, b, e]).T

    df.columns = ['Degree', 'Betweenness', 'Eigenvector']

    df['Node'] = df.index
    df['Node'] = df['Node'].apply(str)


    print("Centrality scores added to network object.")
    return df
```

```
def get_partitions_for_quotient_graph(df, mod_class_column, node_column):
    '''
    Takes in a dataframe with a column for modularity class and a column for the
node (e.g. word, person, etc.)
    Returns a list of sets that can be fed into `nx.quotient_graph()` as equivalent
nodes.
    '''
    parts = df.groupby(mod_class_column)[node_column].apply(lambda x: "%s" % '
'.join(x))
    plist = parts.tolist()
    parts = [p.split() for p in plist]
    parts = [set(part) for part in parts]
    return parts

import pickle
import backboning
import metaknowledge as mk
import pandas as pd
import numpy as np
from sklearn.feature_extraction.text import TfidfVectorizer, CountVectorizer
from sklearn.metrics.pairwise import cosine_similarity
import networkx as nx
import community
import nate

# pre-processed text
parsed = pickle.load(open("data/parsed.pkl", "rb" ))
len(parsed)

# original text
abstracts = pickle.load(open("data/abstracts.pkl", "rb" ))
len(abstracts)

# construct and analyze network
G = nate.construct_simnet(parsed)
coms = nate.get_communities_df(G, print_sizes = False)
cent = nate.compute_centralities(G)
tdf = nate.text_as_node_attribute(G, abstracts)

final = pd.merge(coms, cent, on = 'Node')
final = pd.merge(final, tdf, on = 'Node')
final.to_csv('data/text.csv', index = False)

nx.write_edgelist(G, 'data/final_edgelist.csv', delimiter=',', data=['weight'])

# quotient graph
# mc_partition = nate.get_partitions_for_quotient_graph(coms_cent, 'Modularity
Class', 'Node')
# nx.quotient_graph(G, partition = mc_partition, relabel=False)
```

Appendix C

Scoping review coding manual

Excerpt examples	Code applied
“The aim of this paper is to discuss different methods to visualize energy use in households. We will discuss experience from three different methods, namely information, time-diaries and a power-aware cord. Every method has its drawbacks, but combining the three methods could be one way to highlight households' energy use and their possibility to energy conservation.” “In the paper we analyze the urban form-lifestyle relationships in Finland together with the resulting GHG implications, employing both monetary expenditure and time use data to portray lifestyles in different basic urban forms: metropolitan, urban, semi-urban and rural. The GHG implications are assessed with a life cycle assessment (LCA) method that takes into account the GHG emissions embedded in different goods and services.”	Research questions
“Further, we introduce a concept of 'parallel consumption' to explain how the lifestyles especially in more urbanized areas lead to multiplication of consumption outside of the limits of time budget and the living environment.”	Theories & concepts
“We use a time-geographic visualization to analyse several dimensions of everyday life as a totality. From household members' time diaries, we can analyse and learn about when, where and what energy-related activities occur in the household, involving what household members are engaged and in what wider social context activities are performed.” “Cluster analysis was conducted among 1013 Chinese children aged 9-13 years (49.5% boys) recruited in a cross-sectional survey study.”	Methods & databases
“The retention ratio and the specification of household appliances retained by the single households around universities were surveyed and presented. Even for the single households, although the basic household appliances necessary to conduct living	Findings

activities tend to be retained in general, the specification aspect exhibited large differences compared to general households. In this study, the living activity characteristics of single households were classified by day of week as well as by period, the time required and energy consumption for each living activity were surveyed and analyzed, and quantitative data were presented for energy consumption. In the case of single households, the power consumption was shown to be higher for weekdays rather than for weekends, and during vacations rather than during semester. Improvements/Applications: The results of this study can be utilized when segmented energy consumption analyses are conducted utilizing national statistical data such as Time-Use Surveys.”	

Appendix D

List of 37 captured references for the development/ sustainability research

Full Reference	Cluster(s) in the co-citation network
Antonopoulos, R., & Hirway, I. (2010). *Unpaid work and the economy: gender, time use and poverty in developing countries.* New York: Palgrave Macmillan.	10
Bardasi, E., & Wodon, Q. (2006). Measuring time poverty and analyzing its determinants: Concepts and application to Guinea. In C. Mark Blackden & Quentin Wodon (Ed.), *Gender, time use, and poverty in Sub-Saharan Africa* (World Bank Working Paper No. 73, pp. 75–95). Washington, DC: World Bank.	0
Becker, G. S. (1965). *A Theory of the Allocation of Time. The Economic Journal, 75*(299), 493. https://doi.org/10.2307/2228949	0, 3, 4
Becker, G. S. (1991). *A treatise on the family* (Enl. ed.). Cambridge, Mass: Harvard University Press.	5
Berk, R. A. (1979). *Labor and leisure at home: content and organization of the household day.* Beverly Hills, Calif.: Sage Publications.	0
Berk, S. F. (1980). *Women and household labor.* Beverly Hills, Beverly Hills : Sage Publications, 1980: Sage Publications.	0
Chapin, F. S. Jr. (1974). *Human Activity Patterns in the City: Things People Do in Time and Space.* New York: Wiley	0
Coverman, S. (1983). Gender, Domestic Labor Time, and Wage Inequality. *American Sociological Review, 48*(5), 623–637. https://doi.org/10.2307/2094923	0
De Grazia, S. (1962). *Of time, work, and leisure*. Garden City, N.Y.: Doubleday.	9
Douthitt, R. A. (2000). “Time to Do the Chores?” Factoring Home-Production Needs into Measures of Poverty. *Journal of Family and Economic Issues, 21*(1), 7–22. https://doi.org/10.1023/A:1009423329532	0

Druckman, A., Buck, I., Hayward, B., & Jackson, T. (2012). Time, gender and carbon: A study of the carbon implications of British adults' use of time. *Ecological Economics, 84*, 153–163. https://doi.org/10.1016/j.ecolecon.2012.09.008	73
Esquivel, V., Budlender, D., Folbre, N., & Hirway, I. (2008). Explorations: Time-use surveys in the south. *Feminist Economics, 14*(3), 107–152. https://doi.org/10.1080/13545700802075135	3
Evans-Pritchard, E. E. (1969). *The Nuer: a description of the modes of livelihood and political institutions of a Nilotic people.* New York: Oxford University Press. Retrieved from https://libproxy.wlu.ca/login?url=http://www.aspresolver.com/aspresolver.asp?ANTH;1826070	4
Gershuny, J. (2000). *Changing times: work and leisure in postindustrial society.* Oxford ; New York: Oxford University Press.	0, 1, 3, 10
Ghez, G. R. (1975). *The allocation of time and goods over the life cycle*. New York: National Bureau of Economic Research : distributed by Columbia University Press, National Bureau of Economic Research.	0, 3
Goodin, R.E., Rice, J.M., Parpo, A. and Eriksson, L. (2008), *Discretionary Time: A new measure of freedom*. Cambridge, Cambridge University.	0
Gronau, R. (1977). Leisure, Home Production, and Work--the Theory of the Allocation of Time Revisited. *Journal of Political Economy, 85*(6), 1099–1123.	0, 3
Harvey, A. S. (1993). Time-use studies: A tool for macro and micro economic and social analysis. *Social Indicators Research, 30*(2–3), iii–vii. https://doi.org/10.1007/BF01078720	10
Hill, C. R., & Stafford, F. P. (1980). Parental Care of Children: Time Diary Estimates of Quantity, Predictability, and Variety. *The Journal of Human Resources, 15*(2), 219–239. https://doi.org/10.2307/145332	0
Hirway, I. (2010). Understanding poverty: Insights emerging from time use of the poor. In R. Antonopoulos & I. Hirway (Eds.), *Unpaid work and the economy: Gender, time use and poverty in developing countries* (pp. 22–50). New York: Palgrave Macmillan.	0
Johnson, A. (1975). Time Allocation in a Machiguenga Community. *Ethnology, 14*(3), 301–310. https://doi.org/10.2307/3773258	71

Juster, F. T., & Stafford, F. P. (1985). *Time, goods, and well-being*. Ann Arbor, Mich.: Survey Research Center, Institute for Social Research, University of Michigan.	0, 1, 3, 48
Linder, S. B. (1970). *The harried leisure class*. New York: Columbia University Press.	0, 1, 9, 14
Lundberg, G. A. (1934). *Leisure; a suburban study.* New York: Columbia University Press.	0
Michelson, W. M. (1978). *Public policy in temporal perspective: report on the workshop on the application of time-budget research to policy questions in urban and regional settings*. Laxenburg, Austria. The Hague [etc.]: Mouton.	9
Munroe, R. H., Munroe, R. L., Michelson, C., Koel, A., Bolton, R., & Bolton, C. (1983). Time Allocation in Four Societies. *Ethnology, 22*(4), 355–370. https://doi.org/10.2307/3773682	71
Richards, A. I. (1969). *Land, labour and diet in Northern Rhodesia: an economic study of the Bemba tribe.* (2nd ed.). London: Published for the International African Institute by Oxford University Press.	33
Robinson, J. P. (1977). *How Americans use time: a social-psychological analysis of everyday behavior.* New York: Praeger.	0, 9, 12, 34
Robinson, J. P. (1980). Household technology and household work. In Berk, S. F., *Women and Household Labor*, ed. Beverly Hills, Calif: Sage	0, 9
Robinson, J. P., & Converse. P. (1972). Social change as reflected in the use of time. In Campbell, A., & Converse, P., *Human Meaning of Social Change,* ed. New York: Sage	0, 14
Schmidt, R. M. (1983). Who Maximizes What? A Study in Student Time Allocation. *The American Economic Review, 73*(2), 23–28.	83
Sorokin, P., & Berger, C. (1939). *Time-budgets of human behaviour.* London: Harvard University Press.	0

Szalai, A. (1972). *The use of time: Daily activities of urban and suburban populations in twelve countries*. The Hague: Mouton.	0, 9, 12, 14
Vanek, J. (1973). Keeping Busy: Time Spent in Housework, United States, 1920-1970. (Ph.D.). University of Michigan, United States -- Michigan.	0
Vickery, C. (1977). The Time-Poor: A New Look at Poverty. *The Journal of Human Resources, 12*(1), 27–48. https://doi.org/10.2307/145597	0, 11
Walker, K. E. (1976). *Time Use: a Measure of Household Production of Family Goods and Services.* Washington : Center for the Family of the American Home Economics Association, 1976: Washington, DC: Center for the Family of the American Home Economics Association	0, 7
Zerubavel, E. (1979). *Patterns of time in hospital life: a sociological perspective.* Chicago: University of Chicago Press.	4