Public Transportation and Social Sustainability: Investigating the Use of Indicators to Evaluate Social Sustainability in Public Transportation Systems

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Abstract

For the last 30 years, countries across the world have grappled with how to advance people's quality of life given increasing risks to daily life posed by a changing climate. Among our understanding of the drivers of climate change, the transportation sector in particular exists as a primary source of greenhouse gas emissions and must be reformed to achieve a sustainable society. In recent years, a renewed interest in promoting sustainable transportation has driven sizeable government expenditures, notably as part of the Infrastructure Investment and Jobs Act (IIJA) in the United States. Recognizing the urgency with which large sums of public funds are allocated toward transforming the U.S. transportation system, it is important to possess a means of evaluating if such investments produce the desired outcomes. This project examines one component of sustainability evaluation in the context of public transportation systems. Public transportation is an essential service for millions of individuals on a daily basis to access employment, education, healthcare, basic amenities, and social interactions. However, in striving to make transportation systems sustainable, policymakers and researchers alike often focus their attention on the environmental and economic aspects of sustainability. The social aspect of sustainability and how to evaluate it is much less researched.

I examine the literature published about social sustainability and the proposed approaches to assessing it in public transportation systems. Using a mixed-methods approach, I employ a science mapping analysis to build a visualization of different indicators meant to measure characteristics of social sustainability within public transportation. From this map, I perform a content analysis to distinguish indicators that are clear in their prescribed measurement and analyze the structure of how indicators relate to themes. This analysis assesses how useful current evaluation methods for identifying social sustainability in systems are for today's transit providers and researchers.

Based on the analysis, I find that social sustainability is especially complex, compromised of over a dozen themes that each possess a number of associated indicators. Although some indicators prescribe a clear measurement, many others lack specificity in what the indicator measures or how to carry out that measurement and can vary in meaning based on the geographic scale selected for assessment. Furthermore, existing models evaluating social sustainability in transportation often fail to assess aspects of the transportation system that most affect vulnerable populations, including people living with disabilities. From these findings, I argue that a comprehensive review of existing indicators to provide clear measurements and develop new indicators to account for gaps in assessment of social sustainability is needed to give policymakers and researchers a functional tool for ensuring that sustainability plans address each of the major pillars: environmental, economic, and social. Ensuring balance between these priorities will ensure large investments to reform public transportation systems do not achieve sustainability through environmental and economic objectives at the expense of social outcomes.

Chapter 1 Sustainability & Sustainable Transportation

Sustainability is an ever-present element in the international policy discourse of the twenty-first century. Framed as a response to the climate crisis (Brundtland Commission 1987; Hall 2006; Zhou 2020), recent publications from both the academic and scientific circles across the globe increasingly call for human societies to achieve a sustainable way of life in order to avoid ecological catastrophe (see IPCC Assessment Reports 4 (2007), 5 (2014), and 6 (2022)). The urgency for action communicated through these debates influences policymakers and the types of legislation introduced at both state and federal levels. One emblematic proposal in the United States is the Green New Deal (GND), a legislative effort to decarbonize the modern economic system that emerged shortly after the Great Recession in 2008 (Galvin & Healy 2020). Two of most recent iterations of the GND were proposed by New York Representative Alexandria Ocasio-Cortez, who introduced a GND proposal through House Resolution 109 in February 2019 (116th U.S. Congress 2019), along with Massachusetts Senator Ed Markey who introduced GND through Senate Resolution 166 in April 2021 (117th U.S. Congress 2021).

Transportation and sustainability exist as interconnected issues within the broader sustainability debate. Transportation systems move people, goods, and materials around the world while emitting greenhouse gases (GHG), further accelerating the warming the planet (Elvik 2009; Offer et al. 2010; Sdoukopoulos et al. 2019). Addressing the environmental externalities of existing transportation systems, both the process and supply chain generating energy and fuel to power transportation but also the design of the broader transportation network (i.e., streets, service routes, infrastructure location), is a precursor to creating a decarbonized modern economy. Naturally, much attention is given to the environmental externalities of twenty-first transportation systems and how to mitigate the most harmful effects. More recently though, many sustainability advocates question if simply achieving a net zero emissions system truly constitutes a sustainable society. Transportation systems exist both to facilitate movement but also as tools of oppression (Crockett 2018).

Is sustainability, and by extension sustainable development, only concerned with “clean” or “green” societies? Or elements such as equity and quality of life factor into this improved vision of human existence in the twenty-first century? In this introduction, I briefly explore the origins of sustainability as a concept, how sustainability is viewed within a transportation context, and where the concept of sustainable transportation exists today. These subjects collectively influenced the research questions for this project.

1.1 Origins of Modern Sustainability

Government policies aimed toward creating “sustainable” practices are nothing new. Historians of the modern environmental movement trace its principles back to sustainability policies enacted during the seventeenth and eighteenth centuries, particularly with respect to state-sponsored forest management programs developed in absolutist France and Japan under the Tokugawa shogunate (Caradonna 2014). During the nineteenth century, the Industrial Revolution facilitated a rapid change in resource consumption and humans’ relationship to the environment. With technological innovations such as internal combustion and the subsequent invention of the automobile in the twentieth century, several Western societies rapidly developed around a sprawling pattern of distant, segregated land uses manifesting the modern suburbs. The industrialization of the twentieth century started exposed the consequences of unchecked growth and precipitated the first calls of alarm over environmental

pollution, deteriorating air quality, and overconsumption of natural resources, igniting the modern environmental movement and laying the foundations for sustainability to emerge in its modern form (Ibid).

Environmental concerns that communicated alarm about pesticide use (Carson 1962), the social implications of urban design choices (Jacobs 1961), and pollution of watersheds and ecosystems resulting from land use decisions (McHarg 1969) captured international attention. In response, representatives from around the world gathered in 1972 in Stockholm, Sweden, to convene the first international conference explicitly focused on issues of environmental degradation (UNCHE 1972). The Stockholm Declaration and Action Plan for the Human Environment, which acknowledged the growing environmental degradation resulting from human activity, called for countries across the globe to prioritize environmental stewardship to preserve humanity's way of life (Ibid). This international call revitalized a modern concept of sustainability.

During the emergence of modern environmentalism in the 1960s and 1970s, the United States responded with burst of legislative activity. President Richard Nixon signed several landmark bills into law that remain the cornerstone of environmental regulatory protections in the United States, including the National Environmental Policy Act (1970), an amendment to the Clean Air Act (1970), and the Clean Water Act (1972). Despite the deregulatory movements that occurred in much of the developed world during the 1980s, the voices for humanity to pivot to more sustainable ways of living grew louder. This public call pushed the United Nations to convene a special committee known as the World Commission on Environment and Development (WCED), also known as the Brundtland Commission. In 1987, the group released its report, *Our Common Future*, which advanced sustainability from a concept, or ideal, to a policy objective for countries around the world. The publication formally introduced **sustainable development** as the operationalized goal of the modern sustainability movement (WCED 1987).

1.2 Sustainable Development from Brundtland to Present Day

The Brundtland Commission defined sustainable development as, "meet[ing] the needs and aspirations of the present without compromising the ability to meet those of the future." (WCED 1987, p. 49). Within the framework of sustainable development, the Commission identified four interrelated components: environment, economy, society, and politics (WCED 1987). Following the release of *Our Common Future*, a number of international agreements and conferences sought to advance sustainable development as a policy objective in an effort to reduce greenhouse gas emissions, reconcile economic systems with the resulting environmental degradation, and alleviate the social ills, chiefly global poverty.[1]

Five years later in Rio de Janeiro, Brazil, the United Nations' Conference on Environment and Development (UNCED), also known as the first "Earth Summit", affirmed this sustainability model through policy statements and declarations, namely the document Agenda 21 (UNCED 1992). In addition to defining sustainable development objectives, Agenda 21 also encouraged countries to develop indicators to monitor and evaluate progress towards achieving sustainability goals (UNCED 1992). Sustainable development existed as the framework that allowed countries to achieve sustainability and

[1] These agreements include Agenda 21 (the Rio Declaration) the Kyoto Protocol of 1997, and the Paris Climate Accords in 2015 (UN 2022).

each country was encouraged to develop an evaluation tool to report on progress towards these objectives.

Institutionalizing sustainability continued within governments during the last decade of the twentieth century ultimately popularizing a three-pillar model of sustainability drawn from the Brundtland Commission (Caradonna 2014). The World Bank in the mid-1990s declared its intent to fund only sustainable projects addressing the triple-bottom line of ecology, economy, and equity (synonymous with the three pillars of environment, economy, and society; see Section 3.2 in Chapter 3 for further discussion) (Zegras 2006). Shortly thereafter, the first indicators created to measure sustainability along the three pillars emerged within public policy, most notably in the European Union (see Litman 2003; Zhou 2012). In the United States, similar public policies implicitly addressed progressing towards sustainable development largely in the form of policy statements published by federal agencies notably the Departments of Transportation, Energy, and Housing and Urban Development, along with the Environmental Protection Agency (Zhou 2012). These statements often lagged behind European counterparts for a number of reasons, mostly in their specificity and clear identification of desired outcomes. While sustainable development as a broad policy objective developed during the 1990s, so too did 'sustainable' versions of various economic sectors emerge, notably in transportation.

1.3 Sustainable Transportation

In the United States, greater attention to how transportation systems fit into sustainable development emerged alongside critiques that highlighted the unsustainability of the highway dominated system that existed and its reliance on petroleum-based fuels (Black 1996). Often, these early conversations about how transportation could achieve sustainable development goals (SDGs) emphasized lowering CO_2 emissions (Black et al. 2002; Litman 2003; Jeon & Amekudzi 2005; Zegras 2006). In the 2000s, researchers noted the need for developing indicators that could evaluate elements of sustainability within the transportation system to inform policy decisions and assess how transportation systems met SDGs (Jeon & Amekudzi 2005; Joumard & Gudmundsson 2010; Litman 2007; Zegras 2006). In addition to addressing carbon emissions, early frameworks also proposed evaluating measuring health outcomes related to transportation systems (Jeon & Amekudzi 2005; Litman & Burwell 2006; Richardson 2005). Thus, similar to the concept of sustainable development more broadly, sustainable transport acknowledged the three domains in which to evaluate transportation systems: through environmental, economic, and societal lenses.

Recognizing elements of these three domains within the broad concept of sustainable transportation, numerous definitions arose clarify what this term meant before identifying associated frameworks. Black et al. (2002) contends that sustainable transportation systems provide greater accessibility, protect current environments (including cultural heritages) for the present generation, and does not prevent future generations from meeting these same present needs. Richardson (2005) modified the Brundtland Commission's definition of sustainable development to define sustainable transportation as "the ability to meet today's transportation needs without comprising the ability of future generations to meet their transportation needs" (p. 30, based on Black 1996). Richardson's definition is further broken down into five consequences (safety, congestion, fuel consumption, vehicle emissions, and access). Jeon & Amekudzi (2005) reviewed all 51 U.S. State Department of Transportation websites for operationalized definitions of sustainable transportation systems and concluded that these definitions,

"while varied, capture attributes of system effectiveness and efficiency, and system impacts on the economy, environment, and social quality of life" (p. 31).

Though definitions of sustainable transportation emerged from these studies, real-world examples of how a sustainable transportation operated, and how it could be evaluated at any given time, remained limited. In the literature, some studies have attempted to identify sustainable transportation systems in real-world cities to provide recognizable examples of what such a system looked like and what policies facilitated its development. For example, Jeon et al. (2010) examined the extent of sustainable transportation existing in the Atlanta metropolitan region. Yet, the shift in the focus from the concept to evaluating real-world systems coincided with a concerning, documented trend: GHG emissions resulting from the transportation sector mostly increased worldwide during the early twenty-first century (Sdoukopoulos et al. 2019; Zhao et al. 2020). Recognizing this trend has renewed calls for greater action towards achieving sustainable transportation as part of the broader effort to achieve sustainable societies (Lucas 2019; Sdoukopoulos et al. 2019; Zhao et al. 2020).

Sustainable transportation in the second decade of the twenty-first century became framed in the context of greater attention paid to issues of equity and addressing social exclusion (Karner et al. 2020; Lucas 2012). As a consequence, researchers noted that within sustainable transportation research the conceptualization of the social aspect of sustainability (or social sustainability) remained understudied (Boschmann & Kwan 2008; Opp 2017; Zhao et al. 2020) and lacked a consensus method for evaluation (Richardson 2005; Sdoukopoulos et al. 2019; Wolbring & Rybchinski 2013). Given the present context where governments are heavily investing funds to develop a sustainable transportation system such as in the United States through the Infrastructure Investment and Jobs Act (IIJA), addressing the externalities that affect society resulting from decisions about how to shape transportation systems and services remains paramount. For example, the IIJA proposes to "spend $66 billion to provide healthy, sustainable transportation options for millions of Americans" (White House Fact Sheet 2022).

Whether these solutions will be available to all people living in the United States matters. Yet, with social sustainability lagging behind the other pillars of sustainability (environment and economic) in possessing a ubiquitous, consensus meaning and effective tools for evaluation, such large and rapid investment to transform the transportation system risks perpetuating negative social externalities, such as inequitable access, social exclusion, reduced mobility, and poor health outcomes. Practitioners and researchers alike require an evaluation tool and methodology to make wise decisions in how to shape a holistically sustainable transportation system. This need motivates the purpose of this study and its primary research questions.

1.4 Research Questions

In an effort towards developing an evaluation tool, this project addresses three research questions:

1) How is social sustainability defined compared to the other pillars of the three-pillar sustainability model (environment, economy, and society)?
2) What themes and indicators exist that assess social sustainability within a sustainable transportation system?
3) Which themes and indicators of social sustainability apply specifically to public transportation systems?

The first research question responds to the persistent observation in both sustainability and sustainable transportation literature that social sustainability is understudied compared to the environmental and economic pillars (Vallance et al. 2011; Opp 2017; Zhao et al. 2020). The second question acknowledges the recommendation of Agenda 21, the policy document resulting from the United Nations' 1992 Rio Conference, which states "Countries could develop systems for monitoring and evaluation of progress toward achieving sustainable development by adopting indicators that measure changes across economic, social, and environmental dimensions" (Chapter 8, Section 8.6). The third research question incorporates transportation literature that public transportation use is often necessary for the most socially vulnerable individuals (Sanchez 2008; Palm et al. 2021; Taylor & Morris 2015) and addresses the relative lack of studies that exclusively analyze public transit systems compared to the entire transportation system (Karjalainen & Juhola 2019).

In this paper, I define *public transportation* as a collection of public services (whether free or fee-based service) that provide travel to a rider, also referred to as a user in this context. An example to consider is TriMet in Portland, Oregon. TriMet is a public agency that provides four services: 84 bus routes, five light rail lines (MAX), one heavy rail commuter line (WES), and one paratransit operation (LIFT) (TriMet, 2022). Collectively, these four services create the public transportation system TriMet operates.

I divide the paper into five chapters following this introduction: methodology, literature review, findings, discussion, and a conclusion. As explained in Chapter 2, a literature review serves as the first step in the three-step process supporting the study. In Chapter 3, I examine both the literature in social sustainability as a broad concept and with respect to sustainable transportation. In Chapter 4, I examine the results of a science mapping and content analysis of a Concept Map. Using a science mapping method to display a number of social sustainability indicators identified in the literature, the Concept Map provides a basis for a content analysis of existing indicators that define socially sustainable public transportation systems. I discuss these findings in Chapter 5 and their implications for policy decisions with regard to transportation investment and planning processes. I conclude in Chapter 6 with a summarization of the project's outcomes and highlight how to proceed in future research studies.

Chapter 2 Methodology

I employed a mixed-methods approach to understand how social sustainability is evaluated in transportation systems using public transportation as a specific subsector within the broader system. I decided to narrow the scope to public transportation systems to capture how evaluating social sustainability impacts perspectives about the current state of transportation options for particularly two types of users: transit-dependent individuals, who often possess no other options for accessing transportation outside of public transport services and choice-riders who are often the focus of transit agency's efforts to boost ridership of public transportation (Taylor & Morris 2015). I designed the study to contain three stages.

First, I conducted a literature review of studies examining both social sustainability definitions in the broad context of sustainability research and as applied to transportation systems. From the literature review, I selected studies that presented *indicator frameworks*, which describe a collection of indicators organized according to themes that characterizes a pillar of the sustainability model (Jeon & Amekudzi 2005; Litman 2007; Oswald 2012). I then filtered the studies along four criteria to identify papers that presented social sustainability indicators associated with transportation systems (see Section 2.1 for details).

In the second stage, using an online systems mapping program called Kumu, I applied a science mapping analysis to visualize a map of the qualifying indicator frameworks drawn from the selected studies. I created two maps during this stage. One map includes indicators that applied to the entire transportation system (e.g., road networks, public transportation, air travel, maritime travel, etc.) as not all studies included differentiated indicators by transport sector (Karjalainen & Juhola 2019). From this first map, I then assessed indicators for applicability to public transportation, which resulted in the final Concept Map used for content analysis (see Section 2.2 for details).

In the third stage, I performed a content analysis of the Concept Map to identify the dominant themes (tagged as *primary themes*) and emerging subthemes (tagged as *secondary themes*) that included associated indicators to evaluate how researchers would currently assess socially sustainable public transportation. Next, I recorded the number and content of the indicators associated with each theme. The content analysis of the Concept Map provided insight into how social sustainability is defined, evaluated, and operationalized.

In this chapter, I present the selection process for conducting the literature review and criteria for including certain studies to build the Concept Map. I then discuss the details of each stage of the study. I conclude the chapter with a brief discussion of the research design's limitations and offer recommendations for improving the research design in future studies.

2.1 Literature Review & Indicator Framework Selection

Researchers note that despite the sustainability concept emerging into global policy discourse in the late 1980s, a critical examination of the social dimension or pillar of sustainability did not manifest until nearly a decade after the publication of the Brundtland Commission's report in 1987. Sustainability discourse prioritized the environmental and economic components of sustainability (Colantonio 2009; Dempsey et al. 2009; Griessler & Littig 2005; Opp 2017; Vallance et al. 2011; Woodcraft 2012). This

pattern existed also with respect to examining sustainability in the transportation sector (Black et al. 2002; Litman 2007; Oswald 2012; Zhao et al. 2020; Zhou 2012).

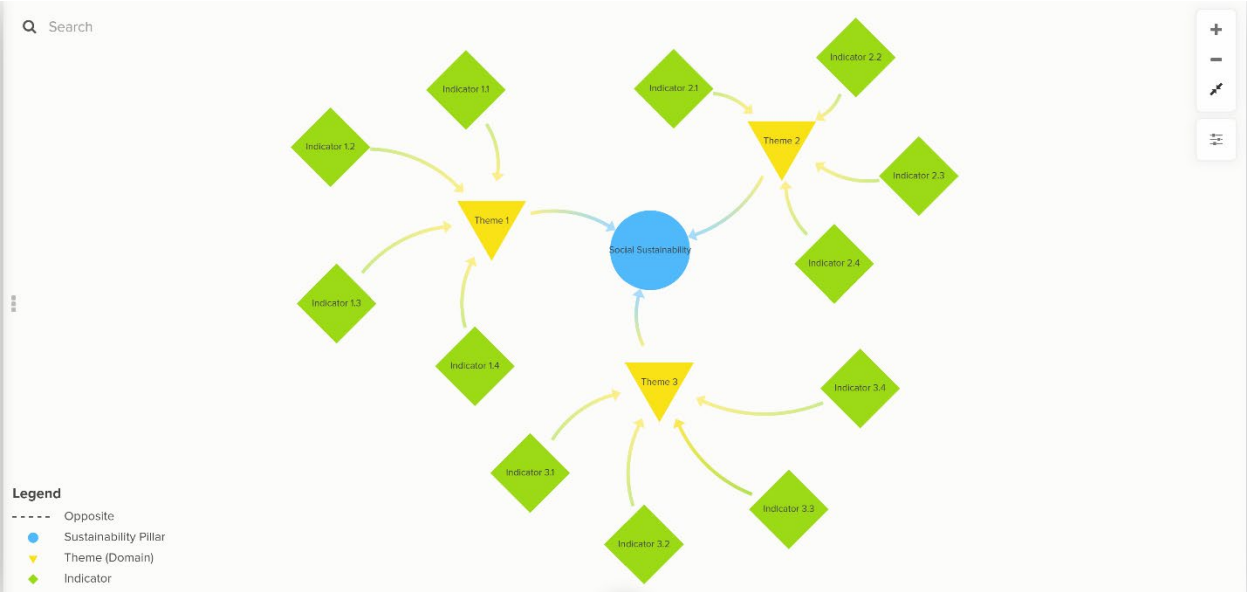
In selecting parameters for reviewing the literature on social sustainability, I chose the publication year for the Brundtland Commission's report *Our Common Future* as a starting point for defining the search period. This decision acknowledges how the framework for viewing sustainability as a policy objective changed following the report's introduction of the now common three-pillar model. The period covers approximately the last 25 years where sustainability as policy exists and advanced sustainability beyond an ideal as it mostly existed prior to Brundtland. The search period for studies includes the period between 1987 and 2022.

Using Google Scholar, I conducted two searches of relevant research articles. First, I applied the keyword *social sustainability* in isolation to identify research that examined social sustainability as one of the three sustainability pillars. Next, I applied the keywords *social sustainability* AND *transportation* to identify the relevant literature where concepts of social sustainability were applied to the transportation sector. The two searches provided a foundation of relevant articles to review and form a selection pool for selecting studies presenting indicator frameworks (see Section 2.2). Ultimately, I collected over 50 studies that included results from each search criteria.

After completing this initial search, I reviewed the studies that explicitly discussed transportation to select a baseline year for studies that present indicator frameworks. I chose Black et al. (2002) recognizing that of the 20 most cited studies in sustainable transport literature since 2000 (see Table 4 in Zhao et al. 2020), Black et al. is the earliest study published. Similar to how sustainability evolved from a modern movement to a policy objective, a clear definition of sustainable transport lagged the broader conversation surrounding sustainability. Literature appears in the late 1990s (Black et al. 1997), before quickly gaining context within transportation systems (Black et al. 2002; Jeon & Amekudzi 2005; Litman 2007; Oswald & McNeil 2010; Oswald 2012; Zhao et al. 2020; Zhou 2012).

I identified 22 studies from the initial search published between 2002 and 2022 that discussed indicators of social sustainability or presented an indicator framework within a transportation context. An indicator framework is an organized structure built between **themes** (for clarity, I use the term *themes*, which is synonymous with terms such as *domain*) and **indicators**. Themes characterize the values or forms that can "define" a pillar of sustainability (i.e., safety is a theme of social sustainability). Themes also function as categories to contain a group of associated indicators. The purpose of indicators is to identify how outcomes support or restrict the desired expression of a theme. For example, if accessibility is a theme of social sustainability, the number of riders within a 10-minute walk can measure how a transportation system affects the expression of theme accessibility. The relationship between themes and indicators can be visually displayed to analyze how to construct an evaluation process for analyzing the degree to which a system operates in a socially sustainable manner. Figure 1 presents a visualization of this conceptual structure. The blue circle represents the sustainability pillar, the yellow triangles represent themes, and the green diamonds represent indicators.

Figure 1. Visualization of Pillar-Theme-Indicator Structure



Each shape is an "element", the functional term used in Kumu.io's architecture, connecting to each other through one-directional arrows that represent connections between levels: from green up to yellow up to blue, or, from indicator up to theme up to a sustainability pillar.

From the 22 studies, I reviewed each of four criteria to determine whether to include them in the science mapping analysis (Section 2.2). Table 1 summarizes how I evaluated each study. If the indicator framework presented in the study violated any of the criterion, I excluded it from the science mapping analysis. This process resulted in 11 qualifying studies. I excluded 11 studies from the science mapping analysis (see Appendix Table 12 for studies and criterion violated). As discussed in Chapter 3, the three-pillar model of environment, economy, and society is predominant in the literature examining systems of sustainability and sustainable development (Karjalainen & Juhola 2019; Kohon 2018; Opp 2017; Vallance et al. 2011; Woodcraft 2012). Therefore, studies that present indicator frameworks from alternative models of sustainability fall beyond the scope of this study. I discuss the implications of this design approach later in this chapter (see Section 2.4).

Table 1: Indicator Framework Selection Criteria

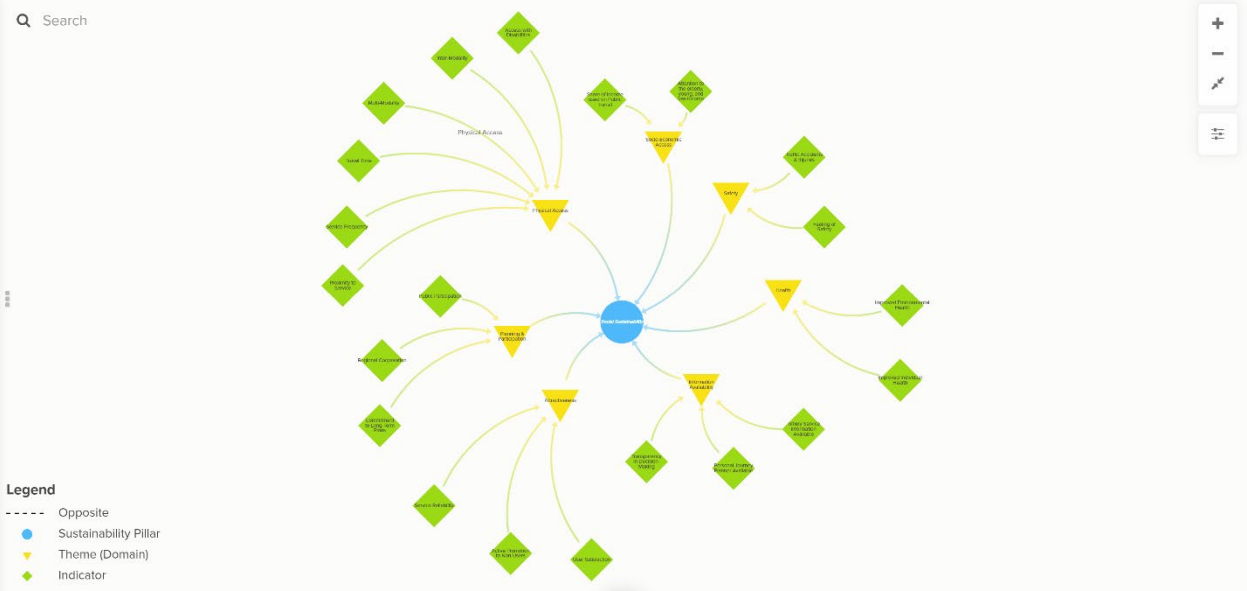
Criterion	Description
Indicators	Must present a clear set of indicators meant to assess elements of the transportation system.
Framework Structure	Must reflect the structure of indicators associated with themes to form an organizational hierarchy.
Focus	Must focus on passenger transport (i.e., no freight).
Pillar	Must include indicators and themes describing social sustainability whether or not other pillars (environmental or economic) are presented.

2.2 Science Mapping Analysis

Findings from the literature review contributed to using a science mapping analysis in the second stage of the study. A need to identify overlaps in definitions, evaluative criteria, and relationships between themes and indicators (see Chapters 3 and 4) emerged while completing the literature review. Science mapping analysis is a method for visually representing relationships, themes, objects, tools, methodologies, or events that characterize a field (Small 1999; Zhao et al. 2020). The method addresses the requirement for producing a "depiction of local structure" (Small 1999, p. 799). Foremost in the method's value is the benefit of displaying a large number of components in relation to one another and identifying important characteristics related to a topic (Zhao et al. 2020).

To perform the analysis, I used an online software tool called Kumu. The application allows users to build different types of visualization maps, including a basic systems map, which I used for this study. In Kumu, the user is able to create connections between "elements" to visually display relationships. Figure 2 shows an example of this visualization architecture using one of the selected studies (Karjalainen & Juhola 2019). In the image, there are seven themes represented by the yellow triangles. The green diamonds represent the 21 total indicators. The arrows show which indicators are associated with each theme.

Figure 2: Kumu Map Example using Karjalainen and Juhola 2019



The sustainability pillar (blue circle) is the social dimension in Karjalainen and Juhola's (2019) sustainable transportation indicator framework. The seven yellow triangles represent the seven themes (called sustainability objectives by the authors). The 21 green diamonds represent the indicators that define each theme.

I used the Kumu system network mapping template to build the Concept Map of the 11 studies that met all qualifying criteria. To distinguish each element as either a *theme* or *indicator*, I applied a "tag" to define the element type when building the map. Figures 3 and 4 display the visualization when this process is applied to the initial example shown in Figure 2. In Figure 3, I applied the *theme* tag to the element labeled **physical access.** In Figure 4, I applied the *indicator* tag to the element labeled **service frequency**.

Figure 3: Coding Tag for Theme Example

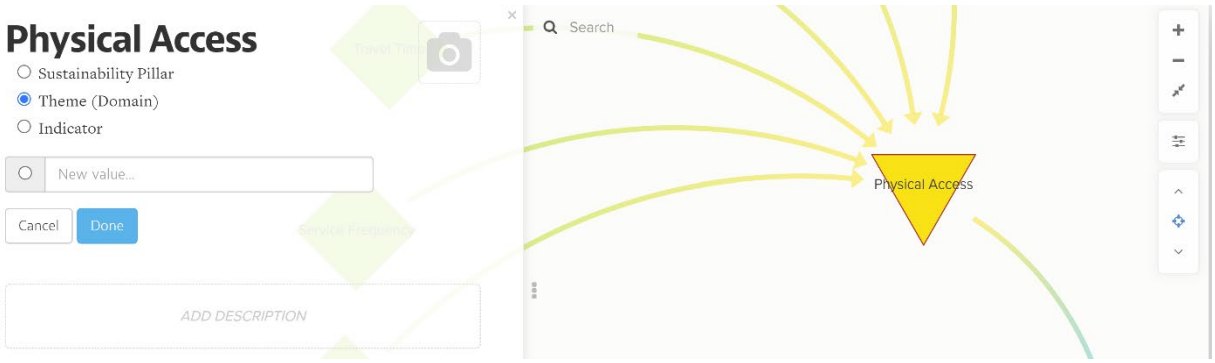
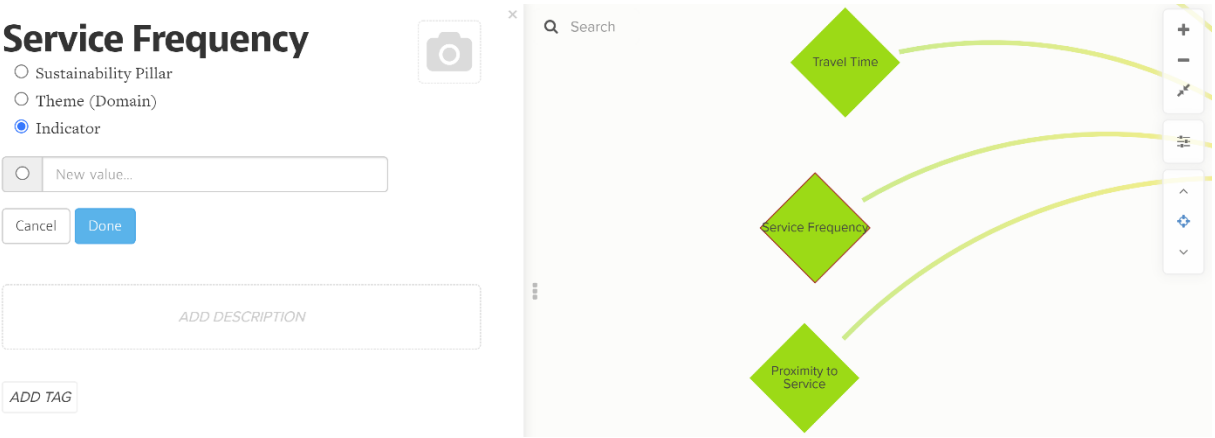


Figure 4: Coding Tag for Indicators Example



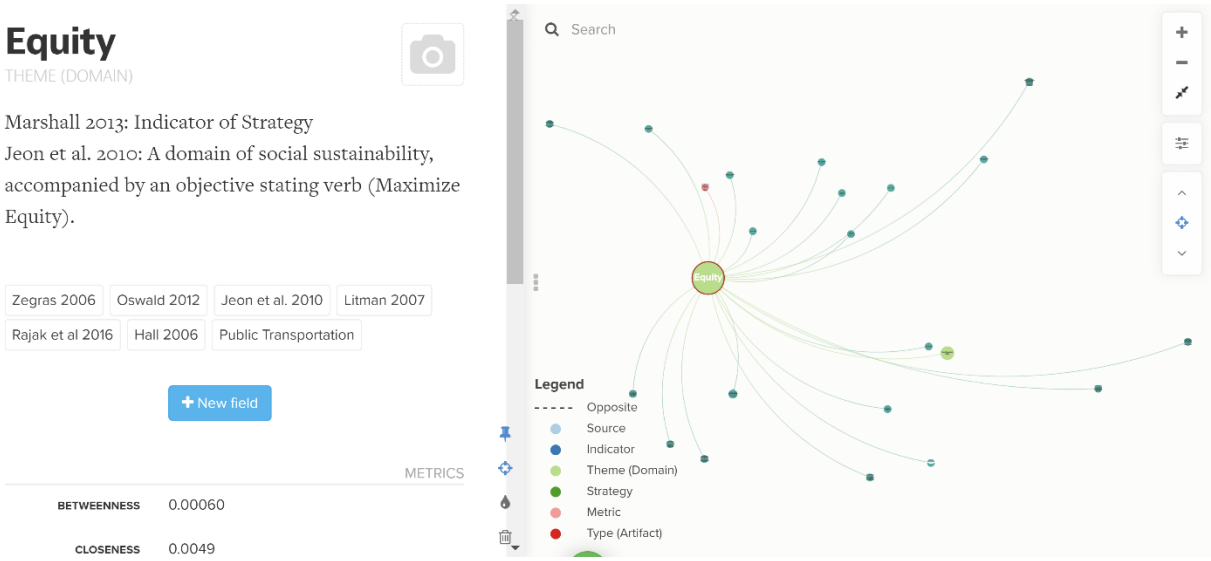
Using Kumu to perform the science mapping analysis structures the research examining social sustainability in transportation systems in a form that can allow for evaluation (Zhao et al. 2020). In addition to tagging each element type as either a *theme* or *indicator*, I also tagged elements based on the source of the indicator framework (see Figure 5). Using the tagging feature, I organized and mapped the 11 indicator frameworks to construct the Concept Map (see Appendix Figure 10) The resulting map included 18 total themes and 118 total indicators.[2]

During the science mapping analysis, I noticed repetition between some themes and indicators after adding more frameworks to the map. For example, after mapping the indicator framework proposed by Karjalainen and Juhola (2019) and then mapping the indicator framework proposed by Jeon et al. (2010) I identified both shared **health** as a theme of social sustainability. In the case of Jeon et al. (2010), the framework categorizes the concept as a "goal and objective", presenting the expression of the **health** theme as an action item: *improve public health*. Within the indicator framework presented by

[2] As discussed in Chapter 3, the majority of studies do not isolate public transportation systems. I first mapped the indicator frameworks from the 11 selected studies, of which only one focuses mainly on public transportation systems (Karjalainen & Juhola 2019). Mapping these 11 studies allowed me to form the first iteration of the Concept Map. From this iteration, I then reviewed each indicator for applicability to public transportation systems to isolate relevant indicators and construct a map applicable to public transportation systems, representing the final draft of the Concept Map.

Karjalainen and Juhola (2019) *health* is a sub-category of the "social sustainability dimension". The two indicators associated with the expression of **health** include the action item to "improve" based on the specific foci. Yet, despite the variance between defining an expression of **health** both frameworks identify **health** as a social sustainability theme. As a result, I tagged **health** with multiple tags showing the frameworks of Jeon et al. (2010) and Karjalainen and Juhola (2019) both exist as sources for this particular theme. Figure 5 shows an example of how I resolved repetitions between frameworks by using multiple tags for elements on the map.

Figure 5. Example of Multiple Tags within Elements of the Concept Map



The Concept Map remains in the right panel visually displaying the relationship and connections between the elements (themes and indicators). The left panel displays information about a selected element. The names of authors (selected studies to map frameworks) and years their studies published in the boxes function as tags to acknowledge sources for the themes and indicators mapped.

I next reviewed each indicator for applicability to public transportation systems to finalize a version of the Concept Map. I evaluated the indicators according to a four-criterion framework (Table 2). Any indicator that explicitly mentions measuring an action or characteristic related to public transportation service is *directly applicable* and the indicator is included in the Concept Map. Similarly, if the indicator explicitly measured an action or characteristic unrelated to public transportation service (i.e., single-occupancy vehicle trip, carpooling, rideshare, taxi, etc.), that indicator was *directly excluded,* and I removed the indicator from the map (see Appendix Figure 10). Other indicators imply applicability or a lack thereof to public transportation systems and I noted which indicators to include in the map when the substance of the indicator implied measuring an aspect of public transportation (*indirectly applicable*). Those indicators that implied a measurement that was not applicable to public transportation were removed from the map (*indirectly excluded)*. Figures 6 and 7 show how I tagged each indicator with its applicability to identify which should be included in the Concept Map.

Table 2: Selection Criteria for Including Indicators in the Concept Map

Criteria Tag	Description	Example Indicator	Theme	Source
Directly Applicable	The indicator explicitly mentions public transportation services (bus, rail, ferry, etc.)	Annual public transportation fatalities per annual unlinked passenger trips by public transit	Safety	Mahdinia et al. 2018
Indirectly Applicable	The indicator describes a topic that does not explicitly exclude public transportation services and can be reasonably applied to the context.	Transport System Diversity	Equity	Rajak et al. 2016
Directly Excluded	The indicator explicitly mentions a measurement of part of the transportation system that excludes public transportation services.	Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily)	Health	Litman 2007
Indirectly Excluded	The indicator describes a topic that often can be interpreted as assessing elements independent of public transportation systems.	Neighborhood Schools - "promote community interaction and increased students' health by providing pedestrian and cycling acess to school."	Accessibility	Oswald 2012

Figure 6: Example of Directly Applicable (DA) Tag Applied to Indicator

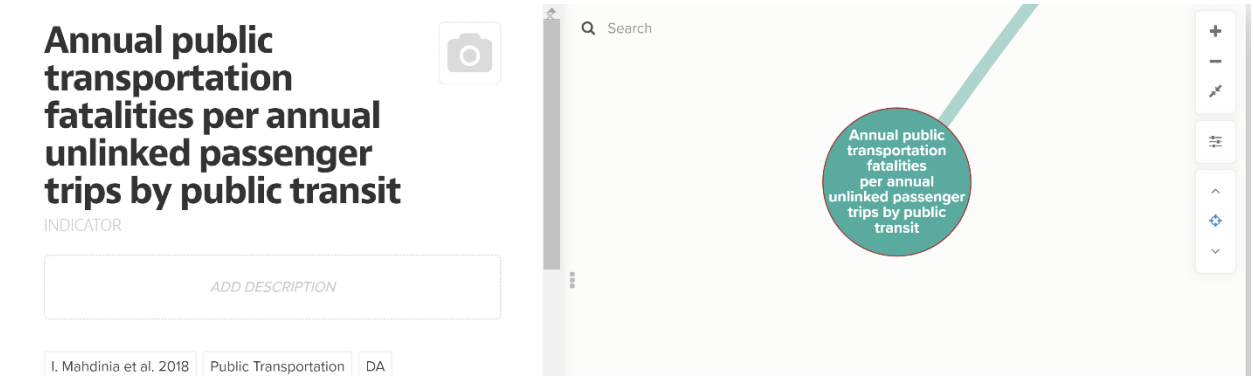
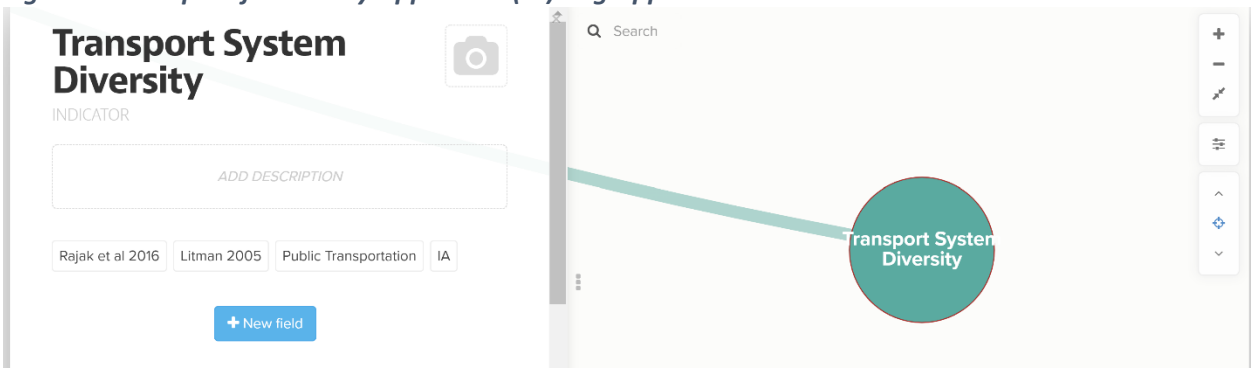


Figure 7: Example of Indirectly Applicable (IA) Tag Applied to Indicator



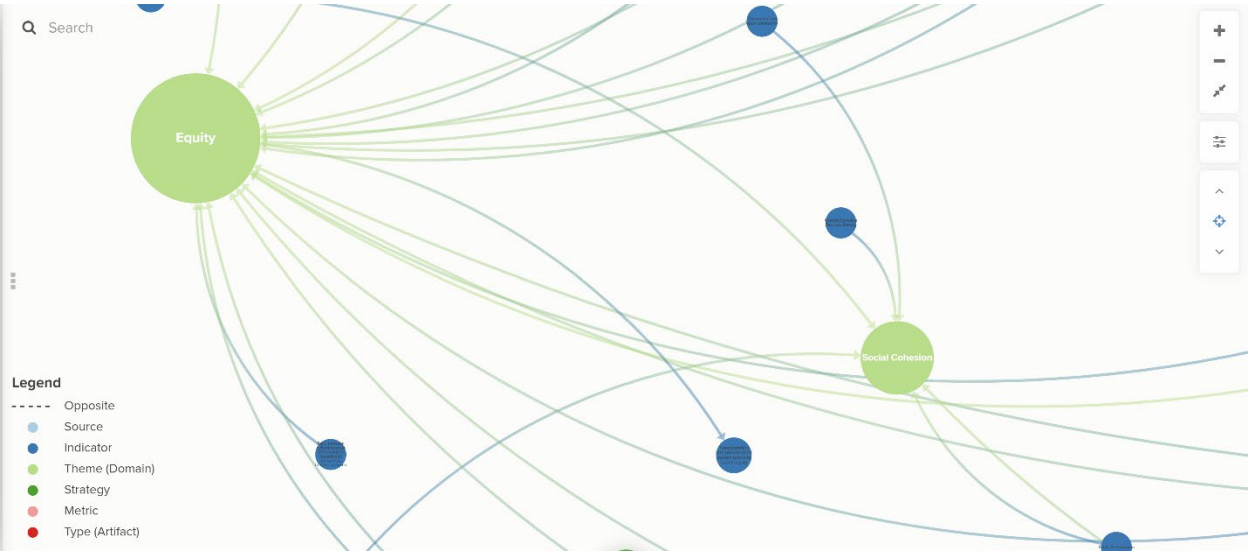
The "DA" tag in Figure 6 and "IA" tag in Figure 7 show that the indicator is applicable to public transportation systems and should be included in the Concept Map.

Once I finished reviewing the indicators for inclusion, I conducted a content analysis of the resulting Concept Map.

2.3 Content Analysis of the Concept Map

I reviewed the resulting Concept Map formed by the connections between elements. To better identify relationships, I sized all the elements based on the number of connections that existed between other elements. This meant that I increased the physical size of any elements tagged *themes* based on the number of connections to elements tagged *indicators*. Figure 8 provides an example of the difference between two *themes* with varying number of connections to *indicators*.

Figure 8. Example of Element Sizes based on Connections in the Concept Map



Due to the greater number of connections between the element labeled Equity and the indicator elements, compared to the element labeled Social Cohesion, the element labeled Equity is greater in size compared to the element labeled Social Cohesion.

I coded four ***primary themes*** based on two distinguishing factors: (a) these themes possessed a disproportionate number of associated indicators compared to the total number of indicators mapped, and (b) multiple studies presented frameworks that included the theme as a component of the social sustainability pillar. I discuss these four primary themes in greater depth in Chapter 4 (Section 4.1). The remaining 14 themes I coded as ***secondary themes*** characterized by two factors: (a) these themes were associated with a smaller proportion of relevant indicators compared to the total number of indicators mapped, and (b) *typically* only one selected study identified the theme as a component of the social sustainability pillar. I discuss these 14 secondary themes in greater depth in Chapter 4 (Section 4.2). Lastly, I recorded the number of total indicators associated with each theme, both primary and secondary.

From the content analysis of the Concept Map, I proposed a working definition of socially sustainable public transportation systems (see Section 4.4). Furthermore, I examined indicators in the map to identify if any indicators addressed gaps in the sustainable transportation literature identified during the first stage of the study (see Section 2.1). I identify these gaps while discussing the outcomes of the literature review (see Chapter 3) and elaborate on implications for policy and future directions for research (see Chapter 5).

2.4 Limitations of the Research Design

The research design included three primary limitations that I expand upon during the discussion of directions for future research (see Chapter 5). First, this study used a narrow and restrictive eligibility criterion to select the studies included in the science mapping analysis. Specifically, the use of the term 'social sustainability' likely excluded studies that describe this concept in a transportation context using different terms, such as 'social equity' or 'social justice'. As a result, it is difficult to claim that the Concept Map is a comprehensive representation of social sustainability's conceptual structure with respect to public transportation systems. Despite this limitation, the science mapping analysis still illuminated an important conclusion that evaluating socially sustainable public transport systems may be more complex than previously recognized. Where Karjalainen & Juhola (2019), who focused their study on public transportation systems, identified 7 themes of social sustainability, this study identifies 18 themes of the same concept.

A second limitation of this study is the subjective approach employed to select indicators to include in the resulting Concept Map. Although I utilized a consistent approach in how I assessed each indicator according to the four criteria, the selection of indicators along the criteria is subject to different interpretations depending on the perspective of the researcher. Other studies may come to different conclusions as to what indicators are most applicable to evaluating social sustainability in public transportation systems. While subjectivity is inherently present within any research design additional studies presenting indicator frameworks for socially sustainable transportation systems should be mapped to account for a greater number of models produced during the research period (2002 – 2022). Furthermore, operationalizing frameworks using selected indicators could be designed as a pilot study to confirm applicability of indicators to evaluating socially sustainable public transportation systems.

Lastly, this study only considered studies published in English. The importance of this limitation is that while it not only excludes potentially relevant indicator frameworks that met the eligibility criteria (see Table 1), since these concepts are socially constructed within the context of one's culture (Campbell 2005), cultural differences in definitions of safety, government process, public participation, and indigenous rights are likely to affect what themes and associated indicators appear in definitions of socially sustainable public transportation systems. Therefore, other conceptualizations of these systems as socially sustainable likely exist beyond the scope of the current study and future studies should explore the concept in non-U.S. or traditionally Western cultural contexts, which constitute a disproportionate focus in the sustainable transportation literature (see Black 1996; Jeon & Amekudzi 2005; Jeon et al. 2010; Litman 2005, 2007; Litman and Burwell 2006; Lucas et al. 2007; Oswald & McNeil 2010; Oswald 2012; Zhao et al. 2020; Zhou 2012).

Chapter 3 Social Sustainability and Socially Sustainable Transportation

As detailed in Section 2.1, I reviewed both the literature examining social sustainability as a concept and the literature examining sustainable transportation as the first stage of this study. In this chapter, I discuss the results and main conclusions from the literature review and divide it into four sections. First, I will explain how I identified relevant articles to include in the literature review. Next, I discuss the findings of the literature review highlighting the persistence of the three-pillar model in sustainability literature as a framework for understanding the concept. Within this discussion, I examine how researchers have disproportionately studied and emphasized the environmental and economic pillars compared to the social pillar of sustainability (Dempsey et al. 2011; Griessler & Littig 2005; McKenzie 2004; Opp 2017; Vallance et al. 2011; Woodcraft 2012).

Following this discussion, I explore how the social pillar, or social sustainability, has been defined and evolved in sustainability literature. It is in this third section that I weave in specific parallels to the sustainable transportation literature, drawing on studies that present potential indicators used to evaluate elements of social sustainability existing within in passenger transport systems (Jeon & Amekudzi 2005; Jeon et al. 2010; Litman 2007; Karjalainen & Juhola 2019; Oswald 2012; Zheng et al. 2013). Lastly, I summarize the main conclusions about the social sustainability literature, both broadly as a concept and specifically in the passenger transportation context. In this concluding section of the chapter, I highlight inconsistencies between definitions that describe themes and exactly what aspect of the system is examined through indicators and how these inconsistencies ultimately influence the degree of subjectivity researchers exhibit in selecting what indicators to apply in evaluating transportation systems. This discussion also addresses the evident gaps that limit effective and consistent evaluation of socially sustainable elements that directly affect transit dependent individuals.

3.1 Keywords and Approach for Identifying Relevant Literature

I employed a series of keyword combinations using Google Scholar to identify an initial group of articles that address the broad concept of social sustainability. For example, I initially input “social sustainability” as one search term. The basic search produced an overwhelming number of records (approximately 271,000 records). I reviewed Pages 1 through 10, or the first 100 results ordered by the search engine’s “Sort by relevance” filter, to identify articles that possessed two characteristics: the highest number of peer-reviewed citations and a title conveying an examination of social sustainability conceptually rather than within the context of a specific topic area. Using this approach, I selected five *foundational articles* to provide a starting point for the broader literature review of social sustainability (see Table 3) and performed both forward and back searches to identify relevant articles.

Table 3: Foundation Articles in the Social Sustainability Literature with Citation Counts

Author(s)	Year	# Citations
Dempsey et al.	2011	1968
McKenzie	2004	1238
Griessler & Littig	2005	1130
Vallance et al.	2011	1066
Eizenberg & Jabareen	2017	494

Source: Google Scholar

After selecting relevant articles that explored the concept of social sustainability, I then conducted searches in Google Scholar combining the terms "social sustainability" AND "transportation", which produced 48,000 records. I refined my search to include the term "indicators" after the initial search, which reduced the results to 27,400 records. Following the same strategy for identifying articles that examined the concept of social sustainability, I identified articles that one, examined social sustainability in a transportation context, and two, also presented an assessment framework for evaluating elements of social sustainability noting the number of peer-reviewed citations to select the most cited articles within the literature. Table 4 displays five articles that served as foundational articles that I performed forward and back searches to collect relevant articles for reviewing the social sustainability of transportation systems literature.

Table 4: Foundation Articles Reviewed in the Socially Sustainable Transportation Literature with Citation Counts

Author(s)	Year	# Citations
Boschmann & Kwan	2008	201
Jeon et al.	2010	125
Rajak et al.	2016	100
Opp	2017	80
Lucas et al.	2007	66

Source: Google Scholar

An important article to highlight, which I identified during a forward-search of Lucas et al. (2007), is Zhao et al.'s (2020) systematic literature review of sustainable transportation literature published in the twenty-first century. Zhao et al. (2020) comprehensively examined 882 articles within the past twenty years, identifying "nine hot research topics" (p. 10) and "four knowledge gaps" (pp. 11–12). The analysis provided an effective wayfinding tool through the literature and partly informed the methods used in this study.[3] Furthermore, this study originally sought to address Zhao et al.'s call to "develop a comprehensive list of social sustainability indicators for transport systems" (p. 12)[4] (see Section 1.3), though as I discuss later in Chapter 4, the analysis of existing indicator frameworks presented barriers to develop such a comprehensive list.

Among the articles reviewed for the two literature review categories, the broad social sustainability literature and the sustainable transportation literature, the defining framework for conceptualizing and operationalizing sustainability in practice remained the three-pillar model. I explore this model in the subsequent section.

[3] Specifically, the science mapping analysis technique influenced this author's choice for how to analyze indicator frameworks, relying on a visualization strategy. Given the author's experience in a previous research project, familiarity with the Kumu open software tool provided a natural pairing between the science mapping method and the online tool.

[4] The scope of this paper deliberately addressed only this component of Zhao et al.'s (2020) knowledge gap of the social sustainability of transport. In addition, Zhao et al. called for exploring the role of Corporate Social Responsibility (CSR) and Social License to Operate (SLO) concepts and potential applications to further promote socially sustainable transport systems, which exists beyond the scope of this research project.

3.2 The Three-Pillar Model of Sustainability

Numerous studies in both the social sustainability literature (Dempsey et al. 2011; Mak & Peacock 2011; Opp 2017; Vallance et al. 2011; Woodcraft 2012) and sustainable transportation literature (Black 1996; Litman & Burwell 2006; Richardson 2005; Zegras 2006) identify the three-pillar model as the predominant framework for conceptualizing sustainability and often attribute the Brundtland Commission's (1987) definition of sustainable development for sustaining the model's popularity among researchers. Examining social sustainability in U.S. cities, Opp (2017) echoed this perspective by describing sustainability as a "three-dimensional concept" (p. 288). Mak & Peacock (2011) highlighted the evolving definitions of sustainable development since the Brundtland Commission (and using the term *sustainability* interchangeably) as bound only in "that [it] is consistency described in terms of three overarching and interacting fundamentals – social, environmental and economical" (p. 2). Richardson (2005), in presenting frameworks for analyzing sustainable passenger and freight transportation systems, noted that regardless of the definition used for sustainable transportation, the definition related back to the "'triple-bottom line' of economic, environmental, and social equity sustainability" (p. 30). In each of these studies, the authors consistently acknowledged the influence of the Brundtland Commission in institutionalizing the three-pillar model as the dominant model for conceptualizing sustainability and sustainable development.

Other researchers criticize the prevalence of the three-pillar model on the basis of the model's inability to account for a holistic viewpoint of sustainability (Campbell 1996; Seghezzo 2009). Additional criticism levied from sustainability advocates note that framing the concept using the three-pillar model presents unrealistic expectations for what it means to achieve sustainability due to presenting the concept as an end-state of existence rather than an iterative, ongoing process of change (Robinson 2004). Despite these criticisms, the three-pillar model persists as the most recognized framework for conceptualizing sustainability since the Brundtland Commission published its report (Purvis et al. 2019).

However, researchers have not given the individual pillars contained in the model the same attention. Within the sustainable transportation literature, studies published more than a decade ago noted this imbalance between the three pillars of environment, economy, and society (Jeon et al. 2010; Richardson 2005; Zegras 2006). More recent studies published within the past five years confirm that imbalance in focus remains (Bamwesigye & Hlavackova 2019; Karjalainen & Juhola 2019; Kohon 2018). In the broader sustainability literature, researchers often prioritize the environmental pillar first and economic pillar second (Opp, 2017; Vallance et al. 2011; Woodcraft, 2012). The lack of attention on the social pillar is not unrecognized among researchers in both planning and transportation disciplines (Boschmann & Kwan 2008; Liu et al. 2020; Opp 2017; Purvis et al. 2019; Shirazi & Keivani 2018; Zhao et al. 2020).

Why did the imbalance between the pillars emerge and why has that imbalance persisted to the present day? I briefly explore the potential factors that explain why environmental and economic sustainability studies constitute a majority of the literature in the next two sections. Following this discussion, I proceed to an in-depth examination of how social sustainability developed within the broader sustainability literature.

3.2.1 The Environmental Pillar of Sustainability

Evaluating the impacts of modern twentieth-century transportation systems is inexorably linked to the issue of environmental quality (Black 1996; Yedla & Shrestha 2003). Increasing automobile adoption during the latter half of the century coincided with a rise in greenhouse gas (GHG) emissions that first alerted the global scientific community to human-driven climate change (UNCED 1972). Since introducing sustainable development as a policy objective (WCED 1987), and affirming the role of sustainable transport in achieving the objective (UN 1992), researchers sought to produce evaluation methods for monitoring the transportation sector's output of GHG emissions (Akerman & Höjer 2005; Amekudzi et al. 2009; Elvik 2009; Joumard & Gudmundsson 2010; Yedla & Shrestha 2003) in order to reimagine how transportation systems could efficiently consume fuel without producing negative consequences that drove environmental degradation (Agrawal et al. 2007; Gerbens-Leenes et al. 2012; Holden & Norland 2005; Offer et al. 2010).

GHG emissions resulting from transportation systems, both passenger and freight transport, became a central focus when the Brundtland Commission released *Our Common Future* (WCED 1987). Since the early 1990s, the sustainable transportation literature extensively evaluates sustainability in the context of freight transport, most often related to global supply chains and their effect on the global economy (Centobelli et al. 2017; Richardson 2005; Russo & Comi 2012; Zhao et al. 2020). For example, Centobelli et al. (2017) developed eight potential research questions from a systemic literature review of logistics service providers and transportation challenges within the context of environmental sustainability. Richardson (2005) proposed a framework analysis of sustainable freight trucking by identifying influencing factors such as trucking safety, road environment, government policies, and vehicle kilometers traveled. Consistent attention paid to freight transportation and logistics supply chain management continued throughout the early twenty-first century (Zhao et al. 2020) and increasingly emphasized potential solutions for reducing fossil fuels use for alternative fuels and power sources (Agrawal et al. 2007; Holden & Norland 2005; Offer et al. 2010).

Another widely studied aspect of sustainable transportation's relationship to environmental quality is the GHG emissions and fuel consumption needs of passenger transport systems (Akerman & Höjer 2005; Amekudzi et al. 2009; Joumard & Gudmundsson 2010; Sdoukopoulos et al. 2019; Zhuang et al. 2021). Research approaches range from evaluating the ecological footprint of passenger transport (Amekudzi et al. 2009) to selecting indicators to monitor negative externalities resulting from transportation, such as CO_2 emissions or noise pollution (Jeon & Amekudzi 2005; Joumard & Gudmundsson 2010). Regardless of whether a study considers freight or passenger transport, focusing on environmental emissions is often a prioritized subject in the sustainable transportation literature, a fact attributable to the urgency associated with growing recognition of the global climate crisis (Karjalainen & Juhola 2019; Zhao et al. 2020).

Emphasizing environmental concerns (Awasthi & Chauhan 2011; Black et al. 2002; Litman & Burwell 2006) also spurred researchers to pay disproportionate attention to the economic pillar of sustainability, often at the expense of exploring characteristics of social sustainability (Boschmann & Kwan 2008; Liu et al. 2020; Zhao et al. 2020).

3.2.2 The Economic Pillar of Sustainability

Sustainable development policies often cite promoting a "vibrant and efficient" economy as an objective for achieving sustainability (Black et al. 2002). Transportation systems inevitably intersect with economic systems, both at the macro- and micro-levels. Thus, sustainable transportation research often emphasizes the economic pillar most often through studies of transport systems offer people accessibility to meet basic needs (Machler & Golub 2011) or to support efficient global supply chains (Sim et al. 2013). Whereas emphasis on the environmental pillar mostly results from an objective of researchers to resolve the conflict between economic and transportation systems (e.g., automobile dependence for commuting or traveling for consumption), the emphasis for addressing the economic pillar originates either from the optimal solution for resolving such conflicts using the principles of sustainability (Awasthi & Chauhan 2011) or examines economic sustainability from the perspective of the cost to the user (Gössling et al. 2022; Machler & Golub 2011). For example, in a recent study comparing the lifetime costs of car ownership among three German car models, Gössling et al. (2022) explored the effects of economic interventions, such as fuel taxes, on households of different incomes that owned a vehicle.

Economic inequality is fairly well studied in the social equity literature and overlaps with issues directly relevant to sustainable transportation (i.e., active modes, high public transit use, electrified vehicles) (Boschmann & Kwan 2008). Studies that examine how transit fares can restrict access to public transit use for lower-income individuals or influence the decision to ride transit further is a common focus among researchers that centers research questions around the economic questions within sustainable transportation studies (Perrotta 2017; Yoh et al. 2016). Much of the data required to monitor these processes is quantifiable and can be incorporated by researchers and practitioners into cost-benefit analyses or scenario based modelling. Expanding the availability and utility of the data has provided researchers with greater and greater insight into the numerous obstacles created by how transit systems are built and designed. In turn, the ongoing activity of collecting the data renders study of the economic aspects of sustainable transportation highly accessible to the research community.

Where then does this current state understanding transportation within the sustainability model, sustainable transportation, leave the third pillar, social sustainability? Shirazi & Keivani (2017) argue that social sustainability remains a significant pillar and must critically be deconstructed to be understood and operationalized within its context. Opp (2017) says of social sustainability that in better defining and measuring it will, "Mov[ing] social sustainability into the mainstream sustainability discussions is needed to ensure resilient and healthy communities in the future" (pp. 302–303). [find one more quote] Researchers acknowledge the gap and thus the need to focus attention on the social sustainability pillar in tandem with the environmental and economic pillars. I next examine the development of social sustainability broadly and then within the sustainable transportation context.

3.3 Social Sustainability

Social sustainability emerged from the Brundtland Commission (1987) and was affirmed during the Rio Conference through the policy statement Agenda 21 (UN 1992). Objectives meant to achieve social sustainability evolved to include meeting basic human needs (WCED 1987, UN 1992), to realizing social equity, to securing representation and decision-making authority within government procedures (Boschmann & Kwan 2008; Opp 2017). Thus, early in the sustainability discourse, social equity appears to function as a synonymous concept for social sustainability. However, social sustainability as a concept

continued to evolve to incorporate other dimensions and theories of application. Notable examples include Vallance et al.'s (2011) often cited threefold schema of social sustainability constructed as 'development sustainability', 'bridge sustainability', and 'maintenance sustainability' and more recently Shirazi and Keivani's (2018) proposal of the "triad of social sustainability" encompassing a three-pillar model of social sustainability organized by concepts of neighborhood, neighboring, and neighbors.

These examples demonstrate how social sustainability evolved from concern over outputs or states-of-being (e.g., social equity, accessibility, safety) to include concern over processes and belief systems. I will explore this evolution in the next section.

3.3.1 Evolving Definitions: Social Equity to Social Sustainability

Social sustainability exists as a complex concept with little consensus among academics and policymakers about its definition. Equity is foundational to the concept of sustaining society or, more simply, that groups of individuals all have their basic needs met (McKenzie 2004). Researchers continually expand the concept to include characteristics relating to government processes (Rajak et al. 2016) and employing growth management strategies in land use development and around transportation corridors (Hall 2006; Oswald 2012).

McKenzie (2004) defined social sustainability as the unit of transaction of "well-being" with the goal to preserve and enhance current "well-being" through access to services and establishing intergenerational equity. In an attempt to offer a simple working definition for social sustainability, McKenzie emphasizes that this concept is both a condition and process. For example, in addition to intragenerational and intergenerational equitable access to key services, McKenzie cites "systems" and "mechanisms" for a community to become aware of its social sustainability as part of the definition. The ability of the community to pass this knowledge on to successive generations is also indictive of its social sustainability. From this perspective, a socially sustainable community must not only experience an equitable lived experience, but possess tools or skills to one, recognize the fact, and two, successfully pass the same tools and skills. McKenzie further acknowledges that most researchers and institutions attempt to measure social sustainability through the development of indicators and frameworks that structured and applied a system of indicators, similar to the treatment of measuring the environmental and economic pillars.

Dempsey et al. (2011) presented their definition of urban social sustainability by defining two domains (synonymous with the word 'themes' in this paper): *social equity* and sustainability of community. Each domain is further broken down into topical criteria. The social equity domain entails "distributive justice" and can be measured through accessibility to essential goods and services, environmental conditions of the localized built environment, and the effect to which social inclusion or exclusion occurs (Dempsey et al. 2011). Sustainability of community describes, "the ability of society itself, or its manifestation as local community, to sustain and reproduce itself at an acceptable level of functioning" (p. 294). The domain is further broken down into five types of indicators: *social interaction/social networks in the community*, *participation in collective groups and networks in the community*, *community stability*, *pride/sense of place*, and *safety and security*.

From another study, Vallance et al. (2011) proposed three paradigms of social sustainability, described as existing in the forms of *development sustainability*, *bridge sustainability*, and *maintenance stability*. Similar to Dempsey et al. (2011), they do not treat social sustainability as either a strictly positive or

negative outcome, but often as a state of being. For example, in discussing the paradigm *maintenance sustainability*, researchers highlight that the core principle is to maintain or sustain a particular aspect, or quality, of life which oftentimes is the "status quo" (Vallance et al. 2011). Examples of this concept in practice include the need to use a private vehicle or enforce specific development patterns (e.g., low-density housing areas that preserve a suburban character). *Development sustainability* on the other hand characteristics how the society allows individuals to meet their basic needs and how the society builds its social capital (Ibid).

More recently, Opp (2017) proposes that social sustainability is a condition where "all people, regardless of race, ethnicity, gender, or income level must, have the ability to enjoy equal access to the fruits of public investment while also being able to satisfy their basic human needs" (p. 291). Opp deconstructs social sustainability along four dimensions and 12 indicators. The dimensions and their associated indicators in this social sustainability framework include both topics of meeting basic human needs as well as possessing equal opportunity for consumption or attainment of goods, experiences, and places not necessary to human survival. For example, *meeting basic human needs* is a dimension of social sustainability associated with three indicators: affordable housing, safety and security, and fair distribution of income (Opp 2017). Another dimension is community and the value of place associated with two indicators: social capital (defined as the networks and relationships in a community that create trust, shared knowledge, and the ability to work together for a common purpose) and social segregation, which Opp further explains results from identifying the ongoing focus on residential segregation by income and race (p. 294).

Over the past twenty years, social sustainability evolved from accounting mostly for meeting basic human needs (UN 1992; WCED 1987), to a concept that recognized a fair distribution of amenities, expanding the concept beyond simply human survival (McKenzie 2004; Dempsey et al. 2011), to a concept that also highlights the role that community identity, sense of place, and political fragmentation (Opp 2017; Vallance et al. 2011) can play in affecting how socially sustainable a place or community is. The evolution of how social sustainability is defined is somewhat reflected in the sustainable transportation literature. Yet, researchers in this field also struggled to arrive at a consensus for defining for how one can recognize, let alone implement, elements of socially sustainable transportation systems.

3.3.2 Socially Sustainable Transportation

Few studies in sustainable transportation literature examine social sustainability in isolation compared to the environmental and economic pillars (Boschmann & Kwan 2008; Jeekel 2017; Lucas et al. 2007; Oswald 2012). Researchers more often develop a concept of socially sustainable transportation in the context of objectives conflicting with the other pillars, most often the conflict between environmental and socially sustainable objectives (Karjalainen & Juhola 2019; Rajak et al. 2016; Zegras 2006; Zheng et al. 2013). A consistent pattern found in the literature with respect to what characteristics socially sustainable transportation is that access to needs in a safe and healthy manner is coupled with fair distribution of public resources and incorporating community input into the planning and decision-making process (Jeon et al. 2010; Karjalainen & Juhola 2019; Lucas et al. 2017; Oswald 2012; Rajak et al. 2016; Zheng et al. 2013). Although most transportation studies treat each pillar of sustainability in tandem with each other, some studies do focus exclusively on the social sustainability concept.

Lucas et al. (2007) provides one study defining socially sustainable transportation along five "areas of progress" (poverty; accessibility to employment, health, and education; safety; quality of life; and housing). Noted previously in Section 3.1, Boschmann and Kwan (2008) advanced the idea of socially sustainable transportation by tracing how equity and social justice outcomes influenced the propensity for social exclusion, which then affects quality of life. Each of these phenomena collectively contributes to what is understood to be a socially sustainable transportation system. Though Boschmann and Kwan (2008) do not present a framework, they emphasize that socially sustainable transportation concerns accessibility and urban form. More recently, Jeekel (2017) examined the potential relationship between social sustainability and mobility, identifying seven themes (accessibility and affordability; safety and security; health; livability and amenity; equity; and social cohesion and working conditions). In each of these examples, one understands that socially sustainable transportation clearly entails the issues of social equity and justice, but also entail issues of urban form, social interaction, community sense of place, and community role in planning processes.

As noted previously, Agenda 21 from the Rio Conference recommends that countries develop indicators to evaluate and monitor progress towards achieving sustainability (UN 1992). Studies in the sustainable transportation literature as a result often examine and propose best practices for developing indicator frameworks to use for evaluating outcomes. I turn next to examining the variations in indicator frameworks and how these variations challenge researchers and practitioners' ability to effectively evaluate socially sustainable transportation.

3.3.3 Indicator Frameworks

Indicator framework refers to the "conceptual structure linking indicators to a theory, purpose, or planning process" (Litman 2007, p.10). Attempts to evaluate elements of sustainable transportation systems using indicators often requires researchers to develop this conceptual structure. For example, Zheng et al. (2013) presents the Transportation Index for Sustainable Places which organizes sustainable transportation along a structure that establishes 3 domains (analogous to the three pillars of sustainability), disaggregates into 12 total elements, and further disaggregates into 19 indicators. Indicators set among the "elements of the social domain" range from assessing how transportation meets basic access needs consistent with securing human health and safety while also promoting social interaction and equity (Zheng et al. 2013). Karjalainen & Juhola (2019) produced a Public Transportation Sustainability Indicator List that organized sustainable transportation by 3 dimensions (again, analogous to the three pillars), broken down among "thematic sub-sets" (p. 7), which contain 40 total indicators, 21 of which assess social sustainability. Studies that focused exclusively on social sustainability within the sustainable transportation literature often follow the same approach in developing an organized structure of indicators to propose tools for evaluation.

Oswald (2012) defined socially sustainable transportation in the context of roadway development by presenting six "categories" (equity; social cohesion; safety; access; public health; and prosperity) that contained indicators that were further broken down into an objective and associated measure of that objective. For example, the indicator *public participation* within the category of **social cohesion** contains the objective, "Promote equitable and democratic participation by members of the public in the planning process as well as implementation of the project" (p. 108). The associated measurement of this objective Oswald (2012) suggests is "Number of public meetings, outreach events, and open forums

held with regards to the corridor project" (p. 109). Oswald's framework includes 23 total indicators of socially sustainable transportation systems, each packaged within an objective and measurement.

The variation between the quantity of indicators contained with varying number of conceptual buckets (common terms identifying this in the literature include *domain, category, area*, and *theme* as used in this paper) often results from the topical context from which transportation is examined (Richardson 2005; Weingaertner and Moberg 2014). Oswald (2012) examined roadway corridor projects at a localized scale while Zheng et al. (2013) examined land-based transportation development at a state-wide level. Karjalainen & Juhola (2019) examined sustainable transportation from the context of public transit. As a result of these variations between topical focus and scale, indicator frameworks do not follow a consistent, prescribed structure, producing evaluation tools that differ in applicability and precision.

The existence of multiple indicator frameworks is not unique to the study of socially sustainability in the transportation sector. Other fields grapple with the same challenges and add complexity as studies emerge presenting their own indicator frameworks for evaluating social sustainability, such as in tourism (Schianetz & Kavanagh, 2011), food systems (Desiderio et al., 2022), and mass housing construction (Karji et al. 2019). Such studies produced a varied list of indicators that evaluate social sustainability extracted and packaged often due to the details specific to their context.

Take for instance Karji et al. (2019), who identified 33 indicators organized into four subcategories when examining mass housing construction projects, which incorporated topics such as increasing proximity to jobs for the residents (livability) and development in a site with relatively flat topography to enable walking and biking (neighborhood characteristics). Desiderio et al. (2022) examined 34 tools that incorporated indicators for measuring social sustainability along phases of food supply chains. In this study, indicators ranged from the percentage of the food supply chain tracked to the percentage of "ethical products bought" by consumers (p. 536).

The multitude of potential measurements for social sustainability represents one inherent challenge to evaluating its presence in our daily lives. Drawing from the previous discussion of broadly defining sustainability, researchers' philosophic principles and the context of the topic of study can influence their development of indicators. Indicator development can also be affected by the scale in which the evaluation takes place (Shirazi & Keivani, 2018). For instance, social sustainability can be examined within neighborhoods (Larimian et al., 2020; Shirazi & Keivani, 2018), at a regional scale (Jeon et al. 2010), or along defined, specialized areas such as transit corridors (Oswald & McNeil 2010).

Considering that the existing literature about social sustainability offers a variety of indicator frameworks over the past twenty years, the objective of this study is not to add yet another unique and contextually based indicator framework to the field. Instead, this study attempts to compile and evaluate the synergy among the frameworks that already exists. Do indicator frameworks conflict in what *themes* express conditions of socially sustainability? Do these *themes* produce similar structures and produce congruent indicators that address the core elements of the theme? Do the indicators adequately provide an evaluation tool, or plainly a measurement, that captures the complexity of the dynamic interaction between social equity, social justice, social exclusion, and quality of life?

To investigate these questions, I employed a science mapping analysis method to visualize existing indicator frameworks used for evaluating socially sustainable transportation systems. Through the

mapping analysis, I compare characteristics of frameworks in relation to one another in order to identify conflict and congruency between these evaluation tools (see Chapter 2 for detailed explanation of the methodology). I present the results of this analysis in Chapter 4.

Chapter 4 Analyzing the Structure and Prescribed Assessment of Indicator Frameworks in Evaluating Social Sustainability in Public Transportation

This chapter details the results of the science mapping analysis I employed to examine different indicator frameworks researchers have presented for evaluating social sustainability in public transportation systems. The first section presents an overview of four primary and 14 secondary themes. I identified most frameworks including as part of the social pillar of sustainable transportation. In addition, I provide a summary about the associated indicators for both primary and secondary themes. I then examine conclusions drawn from a content analysis of the resulting map of themes and indicators (what I refer to as a Concept Map, see Section 4.2).

In summary, the indicators contained in the 11 frameworks included as part of the science mapping analysis present three specific challenges for effectively evaluating social sustainability. As noted in a review of the broader literature (see Section 3.3) indicator frameworks introduce variation between different geographic scales, within different contexts defined by spatial, cultural, and topical characteristics, and purpose for how and why indicators are selected and packaged as an assessment tool. From this discussion, I synthesize the themes presented in the Concept Map to propose a working definition of sustainable public transportation systems (Section 4.3) and conclude the chapter by further narrowing these themes present a working definition of the elements of socially sustainable public transport systems (Section 4.4). The findings from the science mapping analysis provide a basis that inform a discussion of the applicability of working definitions in practice, what gaps exist among the indicators identifying the transportation needs for specific populations, and how to apply existing frameworks in policy decisions when creating transportation plans and prioritizing projects within public transit agencies (Chapter 5).

4.1 Analysis of the Concept Map

The science mapping analysis and selection of indicators for the Concept Map resulted in the identification of 118 total indicators associated with 18 distinct themes. Analysis shows that four themes exist as *primary themes*, characterized as such given their frequency among indicator frameworks and association with a majority of the indicators recorded. Among the six primary themes, the four dominant themes include **safety** (Jeon et al. 2010; Karjalainen & Juhola 2019; Mahdinia et al. 2018; Oswald 2012; Rajak et al. 2016)**, accessibility** (Hall 2006; Jeon et al. 2010; Mahdinia et al. 2018; Oswald 2012)**, equity** (Hall 2006; Jeon et al. 2010; Litman 2007; Oswald 2012; Rajak et al. 2016; Zegras 2006), and **health** (Jeon et al. 2010; Karjalainen & Juhola 2019; Oswald 2012; Rajak et al. 2016; Zegras 2006). These four themes were associated with 72 indicators, or approximately 61 percent, of the total indicators mapped.

To distinguish primary from secondary themes, I observed that primary themes appeared within multiple indicator frameworks included in the science mapping analysis (i.e., Jeon et al. (2010), Mahdinia et al. (2018), and Oswald (2012) each identify **accessibility** as a theme within each's respective indicator frameworks). In addition, primary themes possess a disproportionate number of total associated indicators.

The other 14 themes, categorized as **secondary themes**, mostly originate from only a single indicator framework, and possess fewer associated indicators (see Table 6). For example, only the indicator framework presented by Rajak et al. (2016) identifies **government efficiency** as a theme of social sustainability. Only the indicator framework presented by Karjalainen and Juhola (2019) identifies **information availability** as a theme of social sustainability. A notable finding is the broad range of topics that constitute secondary themes within the analysis. The themes characterize topics that can be considered subjective assessments (*attractiveness* and *opportunities*), topics about ability (*information availability* and *mobility*), topics about individual rights and justice (*government efficiency* and *working conditions*), and topics of representation and process (*diversity* and *planning and public participation*).

Variability exists among the indicators associated with secondary themes as well. Some indicators can be quite clear in what the indicator examines. For instance, the *occupational accidents* indicator under the secondary theme, **working conditions** (Hall 2006). Hall (2006) defines the indicator as the "number of recorded (notified) serious occupational accidents per year and 100,000 employees in the transport sector" (Ibid, p. 536). However, other indicators are less clear about how one could measure or evaluate the subject matter described within the indicator's language. One example of this ambiguity can be found in the indicator of *indigenous rights* for the secondary theme **government efficiency** proposed by Rajak et al. (2016). The indicator is listed among elements of government efficiency derived from the methodology of using fuzzy logic to evaluate sustainable transportation systems but little more is said about the nature of *indigenous rights* that encompasses an assessment of **government efficiency**. To expand on the point, one might ask if the evaluation should be to identify the existence of policy recognizing indigenous rights within a specific context or to identify the application (or exercise) of indigenous rights in forming policy or spurring participation.

Two secondary themes, **social cohesion** (Litman 2007; Oswald 2012; Rajak et al. 2016) and **community livability** (Hall 2006; Litman 2007; Rajak et al. 2016), differ in one characteristic from the remaining secondary themes, mainly in that they appear in multiple indicator frameworks (three frameworks each) rather than only a single indicator framework. However, given the fewer associated indicators provided to evaluate each theme, I concluded that these two themes better reflected the overall criteria for secondary, compared to primary, themes for social sustainability.

Table 5: Primary Themes of Social Sustainability with Associated Indicator Counts & Source Frameworks

Primary Theme	# Indicators	Source Framework
Accessibility	22	Hall 2006; Jeon et al. 2010; Lucas et al. 2007; Mahdinia et al. 2018; Oswald 2012
Equity	21	Hall 2006; Jeon et al. 2010; Litman 2007; Oswald 2012; Rajak et al. 2016; Zegras 2006
Safety	19	Jeon et al. 2010; Karjalainen & Juhola 2019; Lucas et al. 2007; Mahdinia et al. 2018; Oswald 2012; Rajak et al. 2016
Health	10	Jeon et al. 2010; Karjalainen & Juhola 2019; Lucas et al. 2007; Oswald 2012; Rajak et al. 2016; Zegras 2006; Zheng et al. 2013
Total	**72**	

Source: Concept Map Analysis, 2022

Table 6: Secondary Themes of Social Sustainability with Associated Indicator Counts and Source Frameworks

Secondary Themes	# of Indicators	Source Framework
Social Cohesion	6	Litman 2007; Karjalainen & Juhola 2019; Oswald 2012; Rajak et al. 2016
Planning & Participation	6	Rajak et al. 2016
Opportunities	4	Zegras 2006
Mobility	4	Hall 2006
Prosperity	3	Oswald 2012
Working Conditions	3	Hall 2006
Attractiveness	3	Karjalainen & Juhola 2019
Government Efficiency	3	Rajak et al. 2016
Information Availability	3	Karjalainen & Juhola 2019
Cultural Preservation	3	Rajak et al. 2016
Community Livability	2	Hall 2006; Litman 2007; Rajak et al. 2016
Diversity	2	Mahdinia et al. 2018
Level/Quality of Service	2	Hall 2006
Specialized	2	Litman 2007
Total	**46**	

Source: Concept Map Analysis, 2022

In the following subsections, I will discuss the characteristics of the four primary themes and their associated indicators followed by discussing the 14 secondary themes and associated indicators.

4.1.1 Primary Themes and Indicators

Safety

The analysis identified 19 social sustainability indicators (see Table 7) to evaluate safety in public transportation systems. For example, the indicator *annual number of bus passenger fatalities per total number of buses* directly measures and calculates an aspect of safe public transit. However, the indicator *street lighting* may be calculatable but also may require qualitative assessment of the lighting quality at any given time by interviewing or surveying users of these services. Indicators associated with

the primary theme **safety** reflect a focus paid to monitoring instances of *incident*, *injury*, or *fatality*. In examining the list of indicators, one can quickly note where calculations can occur using quantifiable data and where data will need to be collected from public transit users. Although most of these indicators can be used in quantitative analysis, qualitative data remain important to assess nuanced perceptions of safety between different users of public transit systems. Intersectional identities between race, income, gender, ethnicity, immigration status, and physical and cognitive ability produce a myriad range of experiences that can significantly alter perceptions of safety and comfort while using public transit (important to recognize when considering how to apply the indicator *feeling of safety* to an evaluation, for instance). Table 7 displays the 19 indicators, the source of the indicator framework, and the type of data required to apply the indicator in an evaluation.

Table 7: Associated Indicators with Source Frameworks for the Primary Theme, Safety

Indicator	Source	Data Type
Total number of incidents reported	Hall 2006	Quantitative
Total number of deaths and serious injuries per year by category	Hall 2006	Quantitative
Probability that an individual will be killed or injured in an accident while using a mobility system	Hall 2006	Quantiative
Probability of being harassed, robbed, or physically assaulted during a journey	Hall 2006	Quantitative-Qualitative
Feeling of Safety	Karjalainen & Juhola 2019	Qualitative
Human Safety and Security on Public Transport	Rajak et al. 2016	Qualitative
Security	Oswald 2012	Qualitative
Street Lighting	Oswald 2012	Quantative-Qualitative
Incident Prevention	Oswald 2012	Quantitative
Annual number of bus involving in fatal crashes per total buses	Mahdinia et al. 2018	Quantitative
Annual number of bus passenger fatalities per total number of buses	Mahdinia et al. 2018	Quantitative
Annual public transportation injuries per annual unlinked passenger trips by public transit	Mahdinia et al. 2018	Quantitative
Annual public transportation incidents per annual unlinked passenger trips by public transit	Mahdinia et al. 2018	Quantitative
Percentage of annual bus involving in fatal crashes per total annual number of vehicle involving in fatal crashes	Mahdinia et al. 2018	Quantitative
Percentage of bus passenger fatalities per total traffic fatalities	Mahdinia et al. 2018	Quantitative
Annual bus passenger fatalities per annual unlinked passenger trips by bus	Mahdinia et al. 2018	Quantitative
Incident Response	Oswald 2012	Quantitative
Travel Assault (Crime) Prevention	Rajak et al. 2016	Quantitative-Qualitative

Source: Concept Map Analysis, 2022

Accessibility

In total, the mapping analysis identified 21 indicators associated with the primary theme **accessibility** in public transportation systems. Most of the indicators associated with this primary theme can be quantified, though other indicators reflect both quantitative and qualitative characteristics for assessment. As previously discussed with the primary theme **safety**, the **accessibility** theme includes indicators that present challenges to explicitly define what is meant by access. For example, *access to major services* and *access to activity centers*, although quantifiable, remain ambiguous given what services or activity centers should be considered in the assessment (Jeon et al. 2010). The source of the indicator framework (Jeon et al. 2010) fails to elaborate on which major services or activity centers would be most relevant for evaluating access. This ambiguity also exists in indicators that describe growth management concepts, which require further definition to adequately identify what evaluation or measure is meant for the indicator (e.g., *smart growth*, *compact development*, and *smart location*). Table 8 displays the 21 indicators, the source of indicator, and the type of data required for applying the indicator in evaluation.

Table 8: Associated Indicators with Source Frameworks for the Primary Theme, Accessibility

Indicator	Source	Data Type
Eletronic (% of population with Internet service)	Hall 2006	Quantitative
Access to mixed uses (provide accessibility to a mix of uses including public spaces, community-based food production, recreation facilities, housing, and employment locations)	Oswald 2012	Quantitative
% of population with access to transit	Zheng et al. 2013	Quantitative
Access to major services	Jeon et al. 2010	Quantitative
Access to open space	Jeon et al. 2010	Quantitative
Access to activity centers	Jeon et al. 2010	Quantitative
Annual unlinked passenger trip by bus per capita	Mahdinia et al. 2018	Quantitative
Annual unlinked passenger trips by bus per total number of buses	Mahdinia et al. 2018	Quantitative
Annual transportation unlinked passenger trip except bus per total annual public transportation unlinked passenger trips	Mahdinia et al. 2018	Quantitative
% of total motor bus transit route length per total roads length	Mahdinia et al. 2018	Quantitative
% of exclusive and controlled right-of-way motor bus transit route per total motor bus transit route length	Mahdinia et al. 2018	Quantitative
Total motor bus route length per area	Mahdinia et al. 2018	Quantitative
Annual unlinked passenger trips by public transportation per capita	Mahdinia et al. 2018	Quantitative
% of annual work trips by public transportation per total annual work trips	Mahdinia et al. 2018	Quantitative
Annual work trips by (transit, walk, bicycle, motorcycle, taxicab, carpooled, etc.) except drive alone per total annual work trips	Mahdinia et al. 2018	Quantitative
Street network	Oswald 2012	Quantitative-Qualitative
Land use-mix: Number of job opportunities and commercial services within 30-minute travel distance of residents	Hall 2006	Quantitative
Smart location	Oswald 2012	Quantitative-Qualitative
Smart growth	Hall 2006	Qualitative
Compact development	Oswald 2012	Quantitative-Qualitative
Transportation and placemaking system meets basic access needs of all individuals	Oswald 2012	Qualitative

Source: Concept Map Analysis, 2022

Equity

The analysis identified 21 indicators associated with the primary theme of **equity** in socially sustainable public transportation systems (see Table 9). Jeon et al. (2010) state that social sustainability "captures social equity, human health, safety and security, accessibility to basic services, and overall quality of life" (p. 234) suggesting that equity is a sub-component, or theme as identified in the Concept Map, of social sustainability rather than functioning as an analogous concept. The indicators associated with the primary theme **equity** highlight a relative balance between quantitative and qualitative data. Collectively, the indicators also suggest that elements of distributive justice (i.e., *explicitly earmarked public transport expenditures for the disabled and elderly in % of total public expenditures*) and consequences resulting from the placement of infrastructure or routes (i.e., *equity of exposure to noise, emissions*) exist within indicators of the primary theme **equity**. Table 9 displays the 21 indicators, the framework source of the indicator, and the type of data required to apply the indicator in an evaluation.

Table 9: Associated Indicators with Source Frameworks for the Primary Theme, Equity

Indicator	Source	Data Type
Explicitly earmarked public transport expenditures for the disabled and elderly in % of total public transport expenditures	Hall 2006	Quanitative
Equity of Exposure to Noise	Jeon et al. 2010	Quantitative
Equity of Exposure to Emissions	Jeon et al. 2010	Quantitative
Modal Equity	Oswald 2012	Quantitative-Qualitative
Equity of welfare changes	Jeon et al. 2010	Quantitative
Income Equity	Oswald 2012	Quantitative
Affordable pricing	Oswald 2012	Quantitative
Justice of exposure to PM, NO2, CO	Zegras 2006	Quantitative-Qualitative
Ratio between richest/poorest 20% (quintile) households for public transport reliance	Hall 2006	Quantitative
Universal design (consideration of disabled people's needs in transport planning)	Litman 2007	Qualitative
Segregation	Zegras 2006	Quantitative-Qualitative
Justice of exposure to noise	Zegras 2006	Quantitative-Qualitative
Transport system diversity	Rajak et al. 2016	Quantitative-Qualitative
Reduce portions of destinations inaccessible by people with disabilities and low incomes	Rajak et al. 2016	Quantitative-Qualitative
Transportation and placemaking system promote social equity	Marshall 2013	Qualitative
Ratio between richest/poorest 20% (quintile) for transport related household expenditures	Hall 2006	Quantitative
% of easy accessible low floor vehicles in % of the total urban transport fleet	Hall 2006	Quantitative
Ratio between richest/poorest 20% (quintile) households for access to basic services	Hall 2006	Quantitative
% of "self-financing" of transport costs by the users, differentiated by mode	Hall 2006	Quantitative
Civil and human rights	Rajak et al. 2016	Qualitative
Average income of population using transit relative to average state income	Zheng et al. 2013	Quantitative

Source: Concept Map Analysis, 2022

Health

The analysis identified 10 indicators associated with the primary theme **health**. The indicators reflect both calculable measurements of health status as well as mixed data needs (both quantitative and qualitative) that often assess health outcomes (e.g., *improved individual health*). Table 10 displays the 10 associated indicators of the theme, the source framework of the indicator, and the type of data required to apply the indicator in an evaluation.

Table 10: Associated Indicators with Source Frameworks for the Primary Theme, Health

Indicator	Source	Data Type
Traveler Assault (Crime) Prevention	Rajak et al. 2016	Quantitative-Qualitative
Exposure to noise	Zegras 2006	Quantitative
Exposure to particulate matter (PM), nitrogen dioxide (NO2), carbon monoxide (CO)	Zegras 2006	Quantitative
Exposure to emissions	Jeon et al. 2010	Quantitative
Human Satefy-Security on Public Transport	Rajak et al. 2016	Quantitative-Qualitative
Improved Individual Health	Karjalainen & Juhola 2019	Quantitative-Qualitative
EPA Air Quality Index	Zheng et al. 2013	Quantitative
Transportation meets access needs while consistent with human health & safety	Marshall 2013	Quantitative-Qualitative
Transportation demand management	Oswald 2012	Quantitative-Qualitative
Improved environmental health	Karjalainen & Juhola 2019	Quantitative-Qualitative

Source: Concept Map Analysis, 2022

4.1.2 Secondary Themes and Indicators

The analysis identified 14 secondary themes within the PTS Concept Map: **social cohesion** (Hall 2006; Karjalainen & Juhola 2019; Oswald 2012; Rajak et al. 2016), **community livability** (Litman 2007; Rajak et al. 2016), **planning and participation** (Karjalainen & Juhola 2019; Oswald 2012; Rajak et al. 2016), **opportunities** (Zegras 2006), **mobility** (Hall 2006), **prosperity** (Oswald 2012), **working conditions** (Hall 2006), **attractiveness** (Karjalainen & Juhola 2019; Litman 2007), **government efficiency** (Rajak et al. 2016), **information availability** (Karjalainen & Juhola 2019), **cultural preservation** (Rajak et al. 2016), **diversity** (Mahdinia et al. 2018), **level/quality of service** (Hall 2006; Litman 2007; Oswald 2012), and **specialized** (Litman 2007). Among the secondary themes, most possess two to three associated indicators (with planning and participation, opportunities, and mobility exceeding three associated indicators). Furthermore, for the most part, the indicators originate from only one indicator framework (the source study), although some exceptions exist where the same indicator is used in multiple studies.

Notable among the secondary themes is that they exist throughout the research period (2002 – 2022) rather than clustered to either end. For example, Zegras (2006) includes **opportunities** and Hall (2006) includes **mobility** and **working conditions** as secondary themes, where Oswald (2012) introduces **prosperity** a decade ago. The evolution in social sustainability within transportation studies continued, as Rajak et al. (2016) conceptualized **cultural preservation** as a secondary theme drawing on prior studies done by Litman (2005) and Aotearoa (2009). Drawing attention to Karjalainen and Juhola's (2019) Public Transportation Sustainability Indicator List (PTSIL), **information availability** emerges as a secondary theme from the context of examining sustainability within the public transit context. Over the research period established in this study, social sustainability continues to evolve as a concept, growing more complex and resulting in a greater number of potential themes (and by association indicators) that define how to evaluate and operationalize social sustainable transportation systems. Table 11 displays the 14 secondary themes along with their associated indicators, the source of indicator, and the type of data required.

Table 11: Secondary Themes and Associated Indicators for Evaluating Social Sustainability with Source Frameworks

Theme	Indicator	Source	Data Type
Social Cohesion	Employment Stability	Rajak et al. 2016	Quantitative-Qualitative
	Public Participation	Oswald 2012; Karjalainen & Juhola 2019	Quantitative-Qualitative
	Long Distance Commuting	Hall 2006	Quantitative
	Interconnectivity of transport modes	Rajak et al. 2016	Quanitative-Qualitative
	Connected and open community	Oswald 2012	Qualitative
	Context sensitive decision making	Oswald 2012	Qualitative
Planning & Participation	Community capital	Rajak et al. 2016	Quanitative-Qualitative
	Workforce development	Rajak et al. 2016	Quanitative-Qualitative
	Human captial	Rajak et al. 2016	Quanitative-Qualitative
	Commitment to long term plans	Karjalainen & Juhola 2019	Qualitative
	Public Participation	Karjalainen & Juhola 2019; Oswald 2012	Quanitative-Qualitative
	Regional cooperation	Karjalainen & Juhola 2019	Qualitative
Opportunities	Level of service of public transport and slow modes	Zegras 2006	Quantitative
	Accessibility to services	Zegras 2006	Quantitative-Qualitative
	Accessibility to the center	Zegras 2006	Quantitative
	Vitality of the city center	Zegras 2006	Quanitative-Qualitative
Mobility	Passenger kilometers per capita	Hall 2006	Quantitative
	Total passengers on public transit	Hall 2006	Quanitative
	Total passenger per kilometer	Hall 2006	Quanitative
	Passenger kilometers per GDP	Hall 2006	Quanitative

Theme	Indicator	Source	Data Type
Prosperity	Cultural and historical context	Oswald 2012	Qualitative
	Economic development	Oswald 2012	Quanitative-Qualitative
	Employment Growth	Oswald 2012	Quanitative
Working Conditions	Work absences due to accidents and illness	Hall 2006	Quanitative
	Occupational accidents	Hall 2006	Quanitative
	Precarious employment conditions	Hall 2006	Quanitative-Qualitative
Attractiveness	Overall satisfaction rating of transport system	Karjalainen & Juhola 2019; Litman 2007	Quanitative-Qualitative
	Service reliability	Karjalainen & Juhola 2019	Quanitative
	Active promotion to non-users	Karjalainen & Juhola 2019	Quanitative-Qualitative
Government Efficiency	Efficient pricing	Rajak et al. 2016	Quanitative-Qualitative
	Integrated, comprehensive, and inclusive planning	Rajak et al. 2016	Qualitative
	Indigenous rights	Rajak et al. 2016	Qualitative
Information Availability	Personal journey planner available	Karjalainen & Juhola 2019	Qualitative
	Timely service information available	Karjalainen & Juhola 2019	Qualitative
	Transparency in decision-making	Karjalainen & Juhola 2019	Qualitative
Cultural Preservation	Preservation of cultural resources and traditions	Rajak et al. 2016	Qualitative
	Prevention to cultural barriers	Rajak et al. 2016	Qualitative
	Responsiveness to traditional communities	Rajak et al. 2016	Qualitative
Diversity	Sum of squared of differences between modes with equal contributions in four modes: public, private, carpool and taxi, walking; in annual work trips	Mahdinia et al. 2018	Quanitative
	Number of available transit modes	Mahdinia et al. 2018	Quanitative
Level/Quality of Service	Quality of transport for disadvantaged people (disabled, low incomes, children)	Litman 2007; Oswald 2012	Qualitative
	Passenger assessment of level/quality of satisfaction	Hall 2006	Quanitative-Qualitative
Specialized	Housing affordability in accessible locations	Litman 2007	Quanitative
	Transit affordability	Litman 2007	Quanitative
Community Livability	Accessibility to public services	Litman 2007; Rajak et al. 2016	Quantitative-Qualitative
	Accessibility to employment	Litman 2007; Rajak et al. 2016	Quantitative-Qualitative

Source: Concept Map Analysis, 2022

The findings from the science mapping stage and content analysis yielded two conclusions. The first is that a concept of socially sustainable public transit systems is thematically constructed based on a foundation of a few primary themes. One can think of primary to mean “essential” in this context. For example, if the public transit system was not safe to use, it would not be socially sustainable. From a sustainability perspective, if a system lacks one of the pillars, it cannot be characteristic of a completely sustainable system. Ensuring safety, health, equity, and accessibility is necessary to achieve a sustainable transit system.

Second, to reach a full and complete state of social sustainability, the analysis highlights the presence of secondary themes that are not existing in contradiction but each appearing important towards understanding a holistic view of the concept in practice. As previously mentioned, recent studies presented indicator frameworks that included themes **cultural preservation** (Rajak et al. 2016) and **information availability** (Karjalainen & Juhola 2019) as aspects for evaluation through the use of indicators. In a public transportation context, murals painted on the walls of a transit or bus station exist as evidence of the indicator of *preservation of cultural resources and traditions* (Rajak et al. 2016). The planning process where such art is approved exists as an indicator of *responsiveness to traditional communities* (Ibid). Installation of digital kiosks and signage that display arrival and departure times of either bus or trains in multiple languages and mediums (visual and audio) exists as an indicator of *timely*

service information available (Karjalainen & Juhola 2019). Given the development of new secondary themes over the course of the past twenty years, it is reasonable to expect more thematic concepts defining social sustainability will emerge, both broadly and within the transportation context.

In their study, Karjalainen & Juhola (2019) recognize how "social sustainability is described as the most complex and challenging dimension to measure" (p. 5). Analyzing the Concept Map, the challenge readily becomes apparent. Social sustainability indicators developed for transport exhibit variations in the scale, concepts, and applications at which such indicators evaluate conditions of social sustainability.

4.2 Characteristics of the Indicators: Variations in Scale, Concepts, and Application

From the analysis of the Concept Map, I noted three trends across the total group of 118 indicators. The indicators first varied in scale at which they evaluated social sustainability (individual level measurement compared to system-wide); second, the indicators varied in how each conceptualized evaluation topics (for example, the difference between safety and security and how to situate these issues in the social sustainability context related to public transit); and third, the indicators varied in the form of assessment they prescribe (e.g., measurable, evaluative, or predictive). Researchers and practitioners rarely apply indicators using a consistent approach to evaluate social sustainability as a result of the extensive variation presented through different frameworks within the literature.

4.2.1 Scale

Indicators vary in the scale at which they can be applied, both geographically and with respect to population size. Indicators evaluate behavior at either an individual or community level. For example, under the *accessibility* domain, eight of the 30 indicators identified in the Concept Map present a ratio metric for evaluating collective, community behavior, such as *percentage of the population with Internet access* (Hall 2006) and *annual unlinked passenger trips by public transportation per capita* (Mahdinia et al. 2018). The indicators can be useful when applied in a localized context. Nevertheless, anyone selecting to use an indicator must interpret the evaluation described in the indicator definition and recognize how that measurement or application is affected by the geographic scale in which it is applied. Expanding too far out in covering a wide area can obscure disparities between communities and within communities by assuming that a trend displayed by a collective group adequately applies to each individual, known as an ecological fallacy. Therefore, it is important to account for not only the population scale (individual or group) but also the geographic scale (local or regional) under evaluation.

Also, scale can be defined temporally, or in terms of a time expense. Indicators associated with the theme **community livability** (Hall 2006) provide a clear time cost for gaining access as described in the indicator *percentage of households within maximally 15 minutes walking distance from urban green areas*. Commuting patterns can be defined through measurements of distance as found in the **social cohesion** domain with the indicator *long distance commuting*, defined as percentage of commuters commuting daily over distances of more than 10 kilometers (just over 6 miles) (Hall 2006). The example implies there is a time cost to longer commute times, suggesting an inequitable distribution of access via different commute times between workers.

Some indicators leave the definition of the appropriate scale open to the evaluator's interpretation. For example, among indicators associated with the primary theme **accessibility**, Jeon et al. (2010) include the indicators *access to activity centers*, *access to open space,* and *access to major services*. They define **accessibility** contextually in their study of the Atlanta metropolitan region along with characteristics that

include, “higher density residential located closer to jobs along corridors and in activity centers, a higher percentage of housing accessible to transit, a higher percentage of rural land and green space, and a lower percentage of low density housing construction” (Ibid, p. 240). In that assessment, however, one does not know how *access to major services* is defined. It could mean anything between a five, 10, or 15-minute walk or a 15-minute bike ride or 15 minutes station to station on transit excluding wait and transfer times. Nor do the authors elaborate what is meant by services in the study.

The example shows how **accessibility** can be defined temporally, along with accounting for the transport modes available in the vicinity, and is tied to whether one applies an indicator regionally at a metropolitan scale (Jeon et al. 2010) or locally at a neighborhood scale (Larimian et al. 2020). If variations of scale across multiple planes (geographic, population size, and temporal) poses one challenge, another challenge is how assessing social sustainability also varies in how the context of the study informs the construction of indicators and the resulting frameworks that organizing their evaluation criteria.

4.2.2 Conflicts in Concepts and Associations

The analysis of the Concept Map shows that some of the themes and indicators can conflict in how different researchers associate them in a construction of social sustainability. A simple example would be to point out that while **safety** is clearly demonstrated to be a common theme in the previous frameworks for socially sustainable transportation systems (Jeon et al. 2010; Karjalainen & Juhola 2019; Mahdinia et al. 2018; Oswald 2012; Rajak et al. 2016) it also appears as an indicator that evaluates the theme of **health** (Gilbert 2005; Rajak et al. 2016). Marshall (2013) also associated an indicator that incorporated safety as demonstrative of the theme health (*transportation meets access needs while consistent with human health* & *safety*). The implication of indicators addressing multiple themes is that the associated metric (i.e., the definition of what is measured) varies based on the theme the indicator associates with from the researchers’ perspective and within the context of their inquiry. This example also highlights the variations between the structures used by different indicator frameworks to organize evaluative criteria into a useable format.

Another challenging aspect of reconciling this result is defining boundaries between like terms, for instance, what event or outcome one considers within the descriptive purview of *safety* compared to *security*. In an example of how researchers have differed on their categorization of indicators, Marshall (2013) omits the concept of “affordability” from the social dimension in their indicator framework, categorizing the indicators as characteristic of the economic dimension of sustainability, whereas Oswald (2012) includes “affordable pricing” as an indicator of *equity* within the social dimension of sustainability in their framework. Other instances of overlapping associations often exist within how researchers often the themes of **equity** and **health**. Rajak et al. (2016) and Litman (2007) identify the *diversity of the transportation system* as an indicator of equity while Mahdinia et al. (2018) situate *diversity* as a stand-alone secondary theme that can be further assessed through two associated indicators.

4.2.3 Forms of Assessment

Lastly, the indicators within the system assess social sustainability in different ways. Most commonly, the indicator attempts to capture a percentage of the population performing specific behaviors demonstrating a use, or lack thereof, of the transport system (*number of unlinked bus passenger trips per total passenger trips*) or existing in proximity to areas deemed beneficial to quality of life (*access to*

employment or *access to open spaces*). On the other hand, indicators may exist that assess the presence of concepts or approaches to development. For example, within the *accessibility* domain, Hall (2006) cites *smart growth* practices as an indicator while similarly, Oswald (2012) cites *compact development* and *street network* as two indicators while also citing *transportation demand management* as associated with the theme **health**. The form of assessment between indicators evaluating the presence of growth management techniques compared to statistical evaluation requires yet another reconciliation of how best to apply indicators as a practical evaluation tool of current conditions.

Indicators can also take the form of desired outcomes that are intuitively characteristic of the associated domains. Litman (2005) and Rajak et al. (2016) both cite *reducing the per capita traffic casualty (injury and death) rates* an indicator associated with the theme **safety**. Less precise is the indicator *improved individual health* cited by Karjalainen & Juhola (2019) associated with the theme **health**, but also presents an example of indicators used to express desired outcomes resulting from creating social sustainability. In assessing language, **diversity** may exist as a misleading label for what it evaluates absent further context. The two indicators associated with this secondary theme in the Concept Map assess choice of transport modes rather than representative diversity within various aspects of the transportation system, such as employees, decision makers, and users of the system (Mahdinia et al. 2018). Evaluators seeking indicators that assess issues of racial injustice or underserved populations (e.g., low-income and individuals with disabilities) would need to reference the indicators in the **equity** and **health** themes. The example emphasizes the deliberateness required in indicator selection when constructing evaluation tools and procedures.

Lastly, some indicators within the system may in fact be insufficient evaluations given the temporal context of the places being evaluated. A good example exists in the *opportunities* secondary theme introduced by Zegras (2006). Among the five associated indicators, two relate to the importance of the *city center*. As a research study conducted earlier among the indicator sets reviewed and contextually before the expansion of information communication technology (ICT), one must question whether these indicators are in alignment at scale with the purpose of the evaluation for social sustainability as it has evolved today. Though they may not be helpful in their original form, the concepts could be repurposed for consistency of scale (i.e., repurpose *vitality of the city center* to *vitality of the neighborhood center or commons*).

Chapter 5 Discussion of Science Mapping Analysis Results

The Concept Map displays a complex network of conceptual themes that can describe and constitute the elements of a system that can be defined as socially sustainable. Anchored on four primary themes, the challenge presented by this information is how best to extract an approach for consistently evaluating elements of social sustainability in policies and programs that support functioning communities, particularly public transportation as this study examines. After reviewing the 118 indicators included in the Concept Map, three high level conclusions can inform a working definition of socially sustainable public transportation systems.

In this chapter, I examine the three main takeaways of the science mapping analysis results. I then explore how depending on the agency conducting the evaluation, the variation in approach affects how we can develop policies that promote socially sustainability existing in the operation of public transit. Lastly, I conclude the chapter with a discussion about the needs transit providers require to account for the problems created by varied approaches and indicator frameworks. From this discussion I propose how to operationalize a consistent evaluation process informing the decision making that progresses socially sustainable components influencing how beneficial a service public transportation provides its users.

5.1 Focus and Method of Evaluation

Many of the indicators' content implies that evaluating social sustainability can be done along elements where an assumption is made that people have similar trip behaviors or motivations for travel. This perspective exists despite the extensive literature identifying differing trip behaviors and patterns between individuals, both based on their identities in the present and throughout different points in their lives. Homogenizing trip behavior among groups can obscure variations in how individuals use different transit options and risks providing an incomplete picture of traveling needs among a sizable population. This fact is particularly relevant when discussing the evaluation area to be a metropolitan area public transit system, servicing tens of thousands to millions of people every day. In addition, the indicators can present confusion about how best to structure relationships between elements to measure a degree of social sustainability, such as when a topic (i.e., safety) is presented as both a theme and an indicator via different frameworks. Such conflicts present challenges about how to build effective evaluation tools in guiding any form of study into areas of operation.

5.1.1 Defining the Concept and Addressing Application at Geographic Scales

The Concept Map displays a complex array of indicators that can potentially assess the degree of social sustainability within a system, but does provide two clear details that appear consistent among the frameworks included in the map. Social sustainability in transportation is rooted in elements of safe movement for the collective modes that make use of the system, an ability to access needed destinations, it promotes human health, and these benefits extend to all groups that use the system to take advantage of the life opportunities created by effective travel. The extensive field of secondary themes also is clear in suggesting that a number of elements can also assess elements of the system, such as direct participation and authority in planning efforts between government bodies and public bodies representing the users of the service. In thinking beyond the primary themes, what you might think of as the *necessities* of the system, researchers have proposed examining how transportation

systems impacts concepts of livability, or promoting social cohesion and cultural resources, which can either enhance or diminish how well social sustainability is incorporated.

The Concept Map also reveals the differences of geographic scale used in developing indicator frameworks among the studies included in the analysis. This is to say, as the map offers in its comprehensive form is a collection of indicators that vary in applicability from a highly localized scale, such as a neighborhood up to a much larger scale, such as a metropolitan region. The individual drawing on these measurement tools must decide which indicator best fits with the geographic scale under examination. For example, the indicators associated with the theme **social cohesion** often lack restriction on what scale they can be applied toward such as the indicators of *public participation* (Karjalainen & Juhola 2019; Oswald 2012) and *context-sensitive decision making* (Oswald 2012) which provide no further guidance about applying at a neighborhood, district, or municipal scale (within a broader metropolitan region).

Other indicator types, such as *long-distance commuting* (Hall 2006), suggest that certain indicator types may prescribe a particular geographic scale to be best applied. In the example of *long-distance commuting*, Hall (2006) defines the evaluation as the percentage of commuters that travel over distances of 10 kilometers (or just greater than 6 miles), suggesting that this indicator would be inapplicable when evaluating the system at a neighborhood scale but may work when specifically examining a larger district area or section of a metropolitan area. Working through these variations to construct an appropriate framework is left to perhaps staff within transit agencies or city departments that operate public transportation services. For the benefit of the individuals assessing elements of social sustainability reflected in the public transit system, a comprehensive list of indicators tailored to each's most appropriate geographic scale could provide some initial consistency in how to incorporate this third pillar of the sustainability model into daily life.

5.1.2 Persisting Gaps in Indicator Focus

Another characteristic of the indicators in the Concept Map is that indicators often measure travel behavior in an aggregate perspective, assuming most people make similar trips in similar ways. Mahdinia et al. (2018) for example list *annual unlinked passenger trips by public transportation per capita* with no corresponding indicator that measures *linked passenger trips*. An unlinked trip only measures a segment of the overall trip, beginning and ending simply by entering or exiting a vehicle. So, if an individual is taking a bus from the nearest stop to their home to transfer to a light rail station that will transport them to a station closer to a doctor's appointment, that trip registers two unlinked trips, the bus trip, and the rail trip. Transit agencies monitoring performance often use unlinked trips as an indicator of transit utilization (American Public Transportation Association, 2022). Although this situation may result from an omission or fallacy on the part of the staff tasked with collecting the data using this prescriptive indicator as guidance, the inability to collect linked trips may also reflect data limitations.

Despite data limitations, without a corresponding indicator for linked trips included in the framework, a gap exists in capturing how different individuals travel given their needs. Transfers between transit modes are critical for identifying where inequitable service experiences between users may exist, such is a in fare rates, distance of stations to neighborhoods, and frequency of service. In many U.S. cities, a fare is required for each segment of the entire trip between different modes (e.g., paying to ride the bus and then paying to ride the train) (Perrotta 2017). Furthermore, needing to take more trip segments,

and therefore more transfers when using public transit, increases the amount of time spent on the entire trip, often captured as the transfer penalty (Guo & Wilson 2003).

Omitting linked trips as an indicator of **accessibility** creates two data gaps in better understanding transit use. First, division of labor between individuals often influences travel needs. Though such sharing of roles is not necessarily constrained by gender, trip behavior consistently shows that there are differences in how men and women travel often driven by the roles they serve in supporting families. For example, Perez (2019) in her book *Invisible Women: Data Bias in a World Designed for Men* noted that women in Europe were "25% more likely to trip-chain [than men]" (p. 30). Further examining factors such as the age of children in the household, she notes that accounting for the presence of child under five years old, working women will increase their trip-chaining by nearly three times compared to working men (Perez 2019).

Homogenizing trip behavior through aggregating evaluation of people can also inadvertently obscure aspects of how individuals living with disabilities use public transit. In their broad review of academic literature on social sustainability, Wolbring and Rybchinski (2013) noted that fewer than 1 percent of the academic articles included in their review included content related to social sustainability and individuals living with disabilities. Within the Concept Map, Jeon et al. (2010) provide an apt example, proposing three indicators associated with the **accessibility** theme: *access to open space*, *access to major services*, and *access to major activity centers*. Little detail is given along with these three indicators to define how *access* is applied for individuals living with disabilities, which can broadly range from mobility impairments, sensory impairments, and intellectual and developmental disabilities. One may argue that the indicator is appropriate as written and what is needed to account for the needs of individual groups is associated metrics that could further define specific elements of *access* based on the population under consideration. However, precise metrics associated with individual indicators were largely absent from the eligible frameworks that I mapped in the Concept Map.

5.1.3 Resolving Structural Conflicts and Addressing Measurement of Indicators

As noted in Section 4.2.2, mapping each indicator framework in relationship to the others to build a comprehensive evaluation tool presented obstacles to consistent application of a comprehensive framework. The example of how 'safety' is treated within these evaluative frameworks provides a clear example of one obstacle. The concept 'safety' largely exists as a theme tied to dozens of associated indicators (Jeon et al. 2010; Karjalainen & Juhola 2019; Mahdinia et al. 2018; Oswald 2012), but at times exists as an associated indicator of a larger theme, such as **health** (Rajak et al. 2016). Rajak et al.'s indicator *human safety-security on public transport* associated with **health** also signals that there may be a need to examine the specific instances that distinguish safety and security or if they, in context, are synonymous in meaning.

Also noted in Section 4.2.2, a conclusion of the mapping analysis is that indicator frameworks often form as a byproduct of the subject under evaluation and the geographic scale selected for analysis. The framework presented by Zegras (2006) comprehensively examined a transportation system (i.e., commuters, commercial, industrial, public transit operation, etc.) whereas Karjalainen & Juhola (2019) examined specifically public transportation systems in developing their indicator framework. Other studies define the spatial extent of their analysis as regional (Jeon et al. 2010; Zhou 2012), city wide (Oswald 2012) to the neighborhood scale (Kohon 2018). These variations account for the variety, ambiguity, and complexity that exists among proposed indicators for evaluating social sustainability

within transportation, compounded by the lack of studies that deliberately examine public transportation.

In this subjectivity, a clear characteristic of the Concept Map that creates these obstacles is the fact that the measurement component is not always identified. Litman (2007) defines an indicator as "a variable selected and defined to measure progress toward an objective" (p. 10). The key action within this definition is "to measure" and that requires identifying the measurement(s) allowing one to recognize progress or a lack thereof. In evaluating **accessibility**, the indicator *% of annual work trips by public transportation per total annual work trips* (Mahdinia et al. 2018) prescribes a clear measurement to give definition towards an objective. Contrasted with other associated indicators of **accessibility** *access to activity centers* (Jeon et al. 2010) and *smart growth* (Hall 2006), it is clear that although there is an extensive integration of relevant elements to aspects of social sustainability the appropriate measurement is not yet defined for each of these concepts. As a result, planners, policymakers, and researchers continue to face this challenge in performing precise evaluations of social sustainability in transportation systems.

What is needed then is an examination of how indicators can be measured when that specificity is lacking. Advancing the precision of social sustainability indicators offers two solutions to the previously discussed challenges of conflicting structures and conflicting meanings between indicator frameworks. First, undergoing the exercise of assessing how to measure each indicator, offering a metric for what constitutes *access to activity centers* (Jeon et al. 2010) requires critical thinking and further consensus of what type of data can measure the desire outcome. After identifying the required data, a conversation emerges about what collection method will capture the data stimulating innovation in evaluation practices for socially sustainable transportation systems.

Second, in identifying the necessary data, it is possible that certain indicators will prove to require qualitative data that cannot be easily collected or quantified. Particularly with respect to the themes and indicators identified as characteristic of social sustainability, how safe or accessible a transportation system is will depend on the lived experiences of each individual and important details associated with those experiences are not always quantified or easily identified. For instance, the indicator *reported cases of assault*. A clear component of the indicator's application includes the need for an incident that is reported, or in other terms, documented. How would such an indicator capture verbal confrontations or brief but impactful interactions where emotional distress or abuse affects people? Relying only on the quantitative form of data, *reported cases*, the evaluation can overestimate elements of the system's effectiveness, especially in an environment where individuals feel hesitant to step forward with a complaint. In the context of public transportation, missing these critical details is extremely problematic when considering the literature examining the subversive effects of hostility experienced while riding on public transportation and its influence on reducing a person's tolerance for choosing public transportation as an option for travel.

Overcoming the ambiguity in the prescribed measurement for each indicator and resolving the structural conflicts between different frameworks is critical for creating a precise and practical tool for transit agencies and planners to evaluate public transportation systems performance with respect to social sustainability. Without a resolution to those two challenges, using such evaluation tools to inform policy decisions and assess these systems can produce unintended consequences for its users. I will next discuss some of these consequences.

5.2 Multiple Approaches to Defining Social Sustainability from Varying Agencies and Effect on Policy

Variety in indicator frameworks allows for the flexibility of choice, but also results in a higher likelihood of inconsistency in application across geographic scales and different types of transit providers. The choice of scale matters. For example, a transit agency that provides bus service as well as operates and maintains heavy and light rail systems both regionally and within the inner city can choose how to apply *% of people with access to transit* associated with **accessibility** (Zheng et al. 2013) at either a neighborhood or metropolitan scale. Doing each in isolation introduces the potential of misinterpreting the current state of the system.

Isolating the highly local scale of a neighborhood may over- or under-represent people's access to transit when nearby neighborhoods are experiencing better or worse conditions. Likewise, isolating a purely metropolitan area can risk obscuring issues specific to localized places within the region. For example, if three neighborhoods in a city developed at higher densities in close proximity to transit modes, the higher concentration of people living in those neighborhoods could obscure a lack of access to transit for several other neighborhoods that developed at lower densities and further away from public transit services. The calculation could show that two-thirds of people have access to transit within a 10-minute walk while failing to identify that a majority of those individuals live in one third of the city's neighborhoods. Further demographic analysis can identify if the disparity is also characteristic of inequitable access across racial groups, income levels, educational attainment, families compared to individuals living without children, and so on.

The example suggests that both scales are necessary to capture a complete assessment of indicators within an area. However, depending on the type of transit agency, the size of its operation, and the resources available for monitoring, data collection, and evaluation, some agencies may not have capacity to apply indicators to collect data both at local and regional scales. The context in which evaluation is taken is also influenced by the organization's role. A metropolitan planning organization (MPO), organizations that function as local conduits of federal transportation spending and account for areas containing a population of at least 50,000 people, may prioritize different evaluative criteria given its role in regional transportation planning compared to a local bus provider. As previously discussed, defining social sustainability in any context is informed by the perspective of the evaluator. Without any coordination in what indicators should be prioritized to assess the various themes in socially sustainable transportation systems, evaluators and researchers collect different data, perform different analysis, reach different conclusions, and diverge in how they approach service and policy decisions. Therefore, a coordinated approach to the assessment of socially sustainable transportation systems is required.

5.3 Creating a Network of Frameworks and Tools to Scale Assessment Bi-Directionally

In order to implement consistent evaluation of socially sustainable public transit systems indicators must include a defined measurement, whether a singular or multiple metrics. I discussed these challenges in the previous sections of this chapter. If critical consideration for how to measure each indicator results in reducing ambiguity in identifying the subject of assessment, the indicators must then be organized in a structural framework that is widely applicable in multiple contexts. To accomplish this objective, I propose there must be a collection of frameworks tailored to different geographic scales. In addition, a regional data collection process and tool should be developed to support collection needs for both highly local and regional evaluations.

5.3.1 Developing Frameworks of Indicators Designed to Geographic Scale

The first component of implementing a more precise assessment of socially sustainable public transportation systems is to develop a collection of frameworks designed for a different geographic unit of analysis (e.g., a neighborhood or special district). Frameworks should be developed with ease of use in mind so that organizations with limited staff resources can perform an adequate assessment at the most local scales. Creating a collection of frameworks that can be tailored to both geographic scale that is analyzed and the different capacities possessed of large and small transit agencies alike leverages broad applicability to support a robust data collection effort.

More complex frameworks can be designed for larger organizations such as regional transit agencies, state departments of transportation, and larger MPOs. Indicators should be selected strategically to evaluate larger geographic units of analysis, which would include subareas within municipalities (such as boroughs as found in New York City, NY or wards found in New Orleans, LA), transit corridors (areas found adjacent rail lines or bus rapid transit route), as well as aggregated regions (east, west, north, south as defined within the context of the municipality). Drawing from a greater pool of capital and human resources, larger transportation providers should be positioned to execute assessments of socially sustainable public transportation systems at these larger geographic units while also disaggregating data according to a number of metrics that require development (as noted in Section 5.1.1).

Possessing a collection of applicable indicator frameworks tailored to different geographies will still need a process for application in practice. A process is required to coordinate data collection activities and the concurrent analyses performed across transit providers, from local service providers to regional and statewide transportation organizations. In order to support application of indicator frameworks and subsequent analysis of data, a tool is needed to facilitate data collection, transmissions, and storage.

5.3.2 Creating an Interregional Network of Transportation Providers Assessing Sustainable Transportation Systems

As of 2022, the Federal Highway Administration identified a total of 420 MPOs existing in the United States (National Association of Regional Councils, 2022). Given the role MPOs occupy in transportation planning for regional scales and the capital resources MPOs possess, MPOs may offer an anchor point for the creation of a regional network of providers coordinating in assessing socially sustainable public transportation systems.

For example, if local transit providers and organizations executed indicator frameworks at highly localized scales, that data should be fed into a system in which larger organizations can view and access the data. Some MPOs have begun using such models. For example, the Southern California Association of Governments (SCAG) functions as the MPO for Los Angeles County, serving 19 million residents and is the largest MPO in the United States (SCAG 2022). Starting after the formation of the Future Communities Initiative in 2017, SCAG partnered with the technology company ESRI to develop a data management tool called the Regional Data Platform (RDP). The RDP is a managed access system that allows local municipalities and transportation providers to collect and upload data directly into the system's database, where it is viewable by other subscribers and SCAG. Protection features within the RDP prevent local data from being edited or manipulated by anyone other than the entity that collected and uploaded the data (SCAG 2022).

The RDP tool provides a bi-directional exchange of information and synthesis between local agencies and the MPO. The planning staff within the MPO can analyze the data at both local and regional scales to avoid the risk of obscuring important data and convert the data into clear visualizations that benefit local organizations that can access the platform. Viewing data visualizations can inform local providers and municipalities with valuable insight not only into the local context but also how that context exists within the wider regional transportation system.

To further assist local providers and MPOs in data collection efforts, state governments could assist by providing funding streams that allow understaffed agencies to hire resources to expand the data collection capacity for the agency's respective role in the regional network. Grant programs can be created with funding allocated to provide additional capital resources for hiring additional staff temporarily for the purposes of data collection and analysis. The takeaways drawn from the Concept Map along with the recommendations laid out in this chapter can inform the direction of future research studies and operations within transit agencies. In the next chapter, I suggest where future research studies can focus attention.

Chapter 6 Conclusion

In this chapter, I briefly discuss directions for future research and the importance of continuing to develop evaluation tools for socially sustainable public transportation systems. Three primary areas exist where future research studies should address the unresolved issues identified during this study: mapping additional indicator frameworks, identifying measurements for reducing ambiguity about the subject of evaluation for indicators while creating framework structures tailored to different geographic, and exploring an interregional process for data collection, sharing, and evaluating socially sustainable public transportation systems.

6.1 Expand Search Criteria to Identify and Map Additional Indicator Frameworks

One limitation of this study was the restrictive criteria that narrowed the eligibility of which frameworks were included in the science mapping analysis. The methods identified framework types that possessed specific characteristics. For example, Boschmann & Kwan (2008) presented research on the themes that defined socially sustainable transportation but did not provide an indicator framework and therefore was excluded from the mapping analysis. Jeekel (2017) provided themes and suggested some associated indicators but presented their study using a different model of sustainability than the three-pillar model. This study intentionally narrowed the criteria to identify what indicator frameworks would be most similar in organizational structure to assist with comparisons. Incorporating other studies that fell outside these narrow criteria in the science mapping analysis would benefit understanding of the themes that define socially sustainable transportation. In addition, searches were conducted using the term 'social sustainability', which potentially excluded relevant indicator frameworks that encapsulate the same concept using the terms 'social equity' (i.e., for those studies where social sustainability and social equity were synonymous in meaning).

Future studies should continue to screen the literature for other indicator frameworks not identified in this study as well as expand the eligibility criteria to include aspects of social sustainability that are more often found applied to freight transportation systems and the broader highway system, such as the notion of *corporate social responsibility* (Zhou et al. 2020). Identifying additional indicator frameworks and adding them to the Concept Map will further define the conceptual structure according to its primary themes as well as capture emerging secondary themes as social sustainability continues to evolve conceptually within the context of transportation systems.

6.2 Address Ambiguity in Indicator Measurement and Resolve Conceptual Conflicts

With additional indicator frameworks added to the Concept Map, future research studies must resolve the conceptual conflicts between themes and indicators to disentangle the structure and prepare researchers to identify the appropriate measurement associated within each indicator. Boundaries in what ideas entail (e.g., the subjective decision of denoting boundaries between safety and security) will need to go through a systematic review process to form consensus descriptions of each theme and indicator to inform metric development. Such an effort will likely involve a collaboration of researchers, transit planners and policymakers, and community advocates. Through this reconciliation, researchers can reduce the potential for double-counting data points that could result in conflicting conclusions about the performance of the system while also engaging community stakeholders and transit providers alike in critical thinking about which measurements best inform decision-making based on the priorities and values held by technical experts in tandem with users of public transportation.

To the point of incorporating users' perspectives, values, and ideas, equally important is identifying indicators that do not currently exist in measuring socially sustainable transportation systems. Addressing the gap of capturing data that conveys the unique experiences and needs of underrepresented populations, namely women and individuals living with disabilities, is crucial for promoting social sustainability. Omitting indicators that account for unique travel patterns of these users render any framework of social sustainability incomplete. The most immediate consequence is that public transportation services become inequitable by failing to account for population specific travel needs and behaviors. Furthermore, when transit agencies recognize the lack of available data, developing metrics can inform agencies about the data that needs to be collected and provide a basis for understanding what collection methods and resources will need to be applied. That need suggests that a process must exist for data collection, transmission, and storage.

6.3 Explore Logistics of Roles and Responsibilities for an Interregional Metropolitan Network for Coordinating Implementation

Lastly, future studies should address the existing disconnected nature of how sustainability evaluation occurs among numerous transit agencies and based on varying definitions. Tools should be developed and applied in a pilot study as proof of concept that can be scaled to metropolitan areas of similar size in population and number of transit providers. A few models for how data can be collected and scaled between local and regional contexts exist where the MPO acts as a central repository in partnership with a number of local operators. Though evaluation processes will need to be tailored for the context of each place, drawing on a standardized indicator framework that has identified measurement for each indicator and provides indicators that address gaps in measuring the experience of underrepresented groups can support consistent evaluations over time and at different geographic scales.

The need for regional cooperation extends beyond simply the action but should also account for funding needs and may require action from the state government to allocate public funds to support data collection efforts. Logistical questions remain for each region about the best approach to collect data between transit agencies and government departments.

This study presented an analysis of how researchers define and attempt to evaluate social sustainability in public transportation systems. As governments increase spending and investment in the pursuit of sustainable transportation, it is imperative to understand how the social dimension of sustainability is operationalized in a public transportation context and which methods allow for the best evaluation and monitoring of progress toward desired outcomes. Future research is required to understand the social sustainability in public transportation systems and especially how to organize data collection and exchanges between transit agencies to account for variations in geographic scale. Through such an effort, social sustainability can be revived from its status as the "forgotten pillar" of sustainability (Opp 2017).

Chapter 7 References

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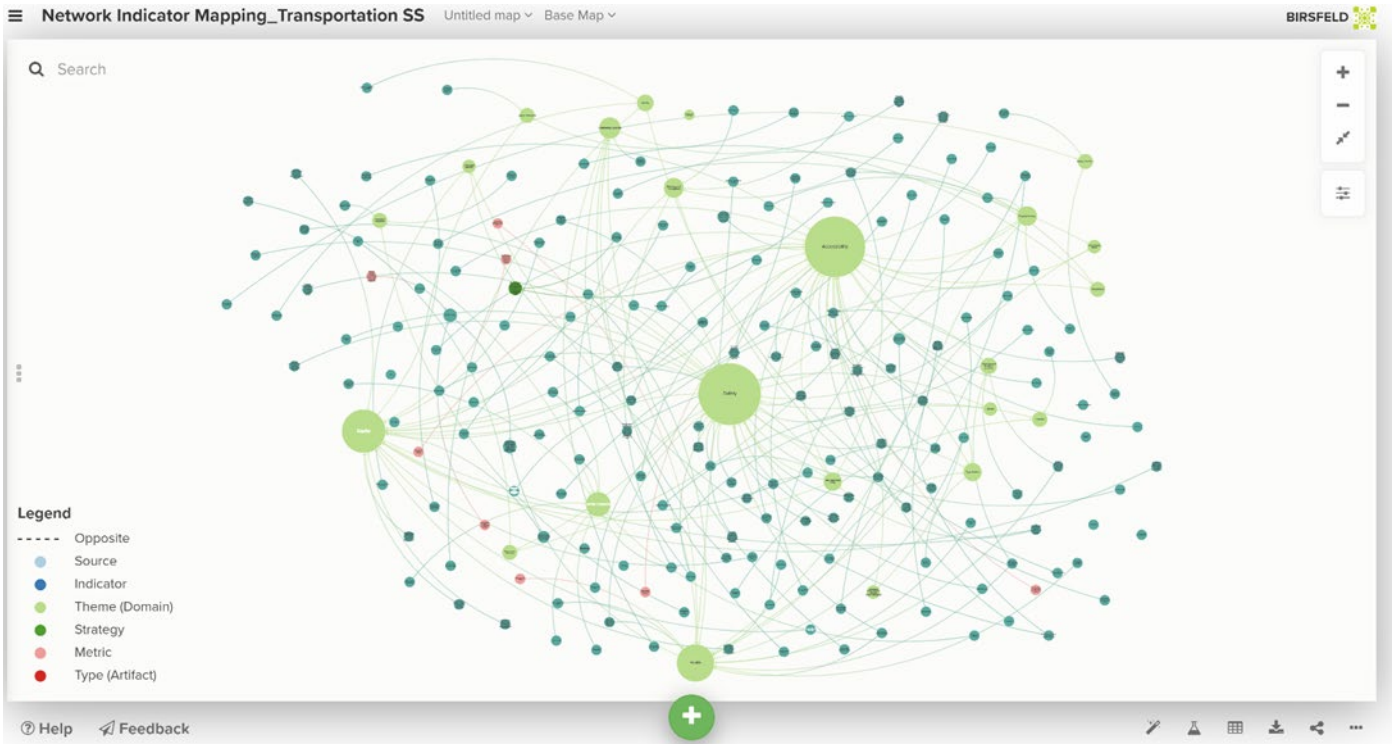
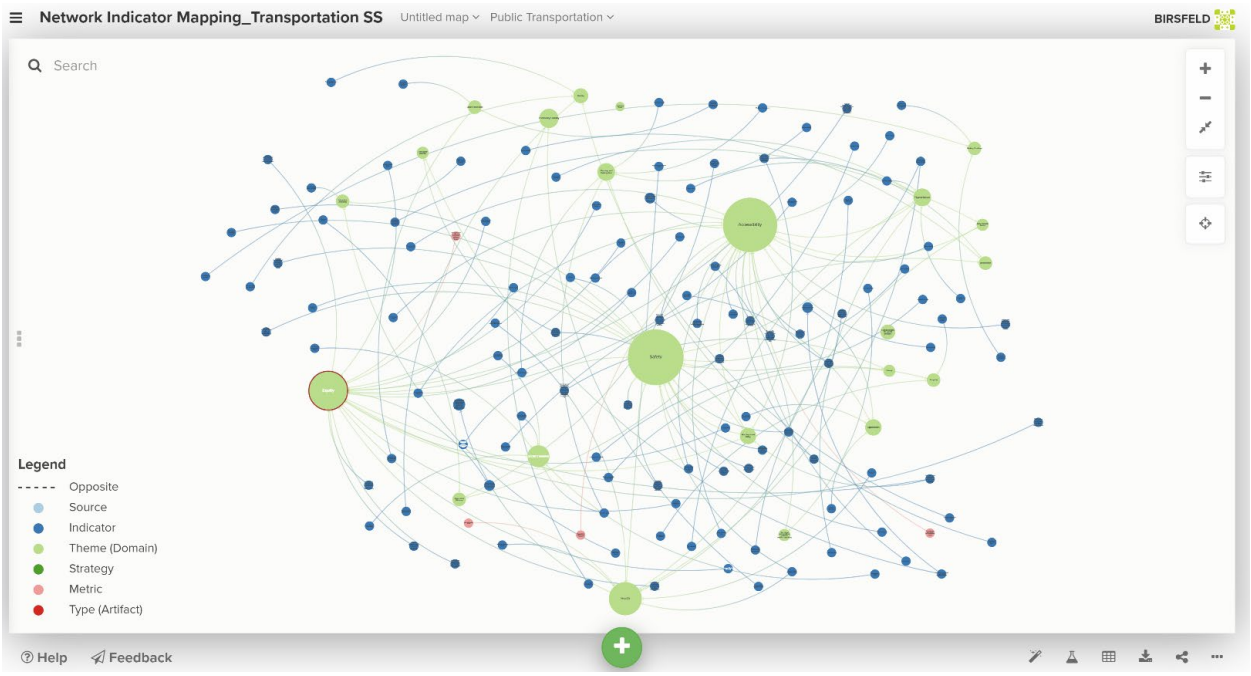
Chapter 8 Appendix: Stages of Concept Map & Excluded Studies from Mapping Analysis

Figure 9: First Draft Version of the Concept Map



Source: Science Mapping Analysis, 2022

Figure 10: Final Draft of Concept Map



Source: Science Mapping and Content Analysis, 2022

Table 12: Studies Excluded from Science Mapping Analysis

Author(s)	Reason for Exclusion
Amekudzi et al. (2009)*	Ecological Focus Only
Bamwesigye & Hlavackova (2019)*	No Indicators Present
Boschmann & Kwan (2008)*	No Indicators Present
Buenk et al. (2019)	Outside 3P Structure
Jeekel (2017)*	Outside 3P Structure
Kumar & Anbanadam (2019)	Freight Transport
Mak & Peacock (2011)*	Non-Transport Focused
Opp (2017)*	Non-Transport Focused
Torre et al. (2021)	Lacks Social Pillar
Wann-Ming (2019)	Outside 3P Structure
Zhuang et al. (2021)	Ecological Focus Only

**included in Literature Review*
Source: Literature Review Process, 2022