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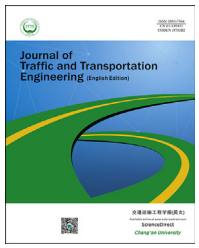

Review Article

Evidence-based practices in sustainable travel behavior intervention: A knowledge graph-based systematic review

Jian Li[*], *Chenjie Xu*

Key Laboratory of Road and Traffic Engineering of the Ministry of Education, College of Transportation Engineering, Tongji University, Shanghai 201804, China

HIGHLIGHTS

- Introduced evidence-based practice in sustainable travel behavior interventions.
- Established evidence-based framework for reliability assessment of interventions.
- Conducted systematic analysis to identify reliable intervention types.
- Converted evidence into knowledge graph and publicized for other researchers.
- Proposed research directions for sustainable travel behavior intervention research.

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ABSTRACT

Sustainable travel behavior intervention is an essential strategy to promote the development of urban transportation. The interventions offer personalized strategies based on certain scenario and participants to promote its effectiveness over hard travel restrictions. However, personalized strategies may also bring about difficulties to identify the actual effect of the measures. Furthermore, based on current practice, to make full use of travel behavior interventions, it is necessary to construct a unified methodological evidence-based framework to assess the reliability and effectiveness of travel behavior intervention studies. In response to these issues, we applied evidence-based knowledge graph to the field of sustainable travel behavior interventions to help decision supporters design sustainable travel behavior interventions wisely and in turn avoid excessive use of hard travel restrictions. We introduced concept of evidence-based practice to conduct a systematic analysis concerning reliability and validity of current full volume empirical studies by dimensions of scenarios, types of interventions and targets. In addition, we took advantage of high extensivity and integrability of knowledge graph to organize evidence-based related elements. Result of the systematic analysis shows that in terms of reliability of evidence, school intervention is the best scenario, knowledge incentive is the best intervention type and promoting public transit and walking proportion are the best targets. Oppositely, the reliability of interventions in workplace, belonging to reward and threat along with aiming at changing travel patterns generally and lowering travel carbon emission need to be enhanced. From the study, various research prospects are raised to promote evidence

* *Corresponding author.*
E-mail addresses: jianli@tongji.edu.cn (J. Li), chenjie_xu@aliyun.com (C. Xu).
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quality in the field of travel behavior intervention implementation. As a pioneer study, our research contributes to the field of urban transportation in introducing concepts of evidence-based practice and enabling optimization and extension of our achievement via the usage of knowledge graph, enhancing reliability and objectivity in urban transportation decision-making.

1. Introduction

Transportation management is an eternal issue in the field of urban transportation to mitigate traffic congestions and related problems due to excessive usage of private motorized vehicles. Transportation management strategies can be classified into two groups (EPOMM, 2023): hard restriction measures involving infrastructure construction or regulations, and soft travel behavior interventions aiming at changing people's travel behaviors by intervention strategies. Hard restriction measures, such as limited license pass, license quota auction and low emission zone, can show the effect instantly. Yet, hard restriction measures fail to change travelers' psychological cognition towards travel behavior, resulting in the decline of the effect in the long term. Compared with hard restriction measures, soft travel behavior interventions offer personalized strategies to change travelers' psychological cognition based on certain scenario and characteristics of travelers. This enables it to outperform hard restriction measures for travelers adhere to changed behaviors in long term. With multiple targets including peak travel avoiding (Li et al., 2021), physical activity promotion (Reema et al., 2010), multimodal travel enhancing (Tsirimpa et al., 2019; Xu et al., 2022) and so on, travel behavior interventions have great development potentials. Thus, travel behavior interventions should be emphasized against hard restriction measures. However, the advantage of personalized rather than fixed intervention strategies may instead bring about difficulties in figuring out mechanisms of interventions as for different scenarios, types of participants and ways of implementation in empirical studies. Furthermore, few participants, no comparison groups or invalid data processing in some studies may also lead to unreliability of evidence, which reduces its reference value in the decision-making process. Thus, even if some travel behavior interventions seem to be effective in some studies, due to the possibility of being unreliable, decision supporters may not run the risk of adopting the result of the studies and carry out hard restrictions measures instead, which blocks its development. Therefore, to make full advantages of travel behavior interventions, it is necessary to construct a unified methodological framework to assess the reliability and effectiveness of travel behavior intervention studies by means of systematic reviews, which is the main significance of our study.

Evidence-based practice, firstly adopted in the field of medicine, provides us with a point of entry to conduct the systematic review. Originating in the 1980s, evidence-based medicine was defined by one of its founders David Sackett as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996). From Sacket's definition, we can conclude that evidence-based practice emphasizes the search of the best evidence and evaluation of evidence rather than reliance on cases, past experience and subjectivism, so as to improve reliability. As for evidence-based medicine, applications and assessments of full volume of current evidence to evaluate effectiveness and efficiency of medical interventions are the focus (Andreas et al., 2021; Mikolajewska et al., 2021; Popp et al., 2021). The assessments of reliability, effectiveness and precision of evidence enable medical practitioners to choose the best evidence into medical applications. Recently, evidence-based practice has been rapidly promoted in fields such as social science (Bai et al., 2022a, 2022b; Li et al., 2022a,2022b; White, 2022), pedagogy (Lă, 2017; Sato et al., 2019), and librarianship (A'dillah and Noorhidawati, 2022; Derven and Kendlin, 2011), just as evidence-based medicine does. The advantage of evidence-based practice can solve the problems of subjectivism in these fields, which in turn improves reliability in decision-making. In the field of travel behavior intervention, however, the concept of evidence-based practice has hardly been adopted. This is indeed the reason why travel behavior interventions cannot replace hard restrictions despite the advantages. Thus, it is necessary and feasible to introduce the concept of evidence-based practice to construct a systematic review of the type, reliability, and effectiveness of evidence, which can be used to support relevant decision-making processes, and reduce subjectivism in the process.

Knowledge graph, firstly applied by Google in its search engine in 2012, is a relatively new technology (Singhal, 2012). Compared with relational database, knowledge graph stores data in the form of triples, which can be converted into a graph (G). It can be expressed as $G = (E, R, S)$. E represents set of entities, R represents set of relations, and S represents triples of entities and relations. Knowledge graph is advantageous in its high expansional potential. This enables it to integrate data from different sources and with different structures. Thus, heterogeneous data can be stored in a unified way. This advantage enables people to optimize existing knowledge graph by enriching it, providing convenience in promotion of knowledge graph. In addition, knowledge graph is also beneficial in its graph structure for the usage of graph related algorithms, favoring the searching of objects in the database. Furthermore, featuring

knowledge fusion (Muppalla et al., 2017; Zhou and Chen, 2019) and knowledge reasoning (Chen et al., 2020; Peng et al., 2017) as two main applications, knowledge graph is thus popular in many fields. Therefore, evidence-based knowledge is an effective tool to store and represent evidence-based empirical studies for decision supporters to understand them better. With the development of knowledge graph, evidence-based knowledge graph, combining advantages of concepts of evidence-based practice and data structure of knowledge graph, is becoming a research hotspot. Currently, usage of evidence-based knowledge graph has been applied to some evidence-based medical research by storing and analyzing medical evidence to guide evidence-based medical decision-making, such as impacts of variable non-pharmacological interventions to COVID-19 pandemic (Yang et al., 2021), relationships among rare diseases (Zhu et al., 2021), complications of type 2 diabetes risk analysis (Wang et al., 2020) and early diagnosis of chronic kidney disease decision support (Li et al., 2022a). At present, as neither evidence-based practice nor knowledge graph has much usage in the field of urban transportation, few studies applying evidence-based knowledge graph have been conducted in this field. Thus, it is necessary to introduce evidence-based knowledge graph into this field. The advantages and significance of evidence-based knowledge can thus be illustrated.

In our study, we applied evidence-based knowledge graph to the field of sustainable travel behavior intervention. Therefore, we built an evidence-based knowledge graph regarding sustainable travel behavior intervention from current literature and carried out an evidence-based systematic review of full volume of evidence concerning sustainable travel behavior intervention. The systematic review contained reliability and usage distribution of evidence categorized by scenarios, types of interventions and targets. With the result of systematic review, decision supporters can have a better understanding of the reliability and usage of current evidence, which in turn aids them to decide how to design and conduct sustainable travel behavior interventions in reality.

Our contributions are two-folds: (1) in the usage of evidence-based practice, it is a pioneering evidence-based analysis in the field of urban transportation. Currently, no evidence-based related studies have been conducted in the field of urban transportation. For a research hotspot, evidence-based knowledge graph deserves more coverage in other fields, especially in the field lacking unified evidence-based methodological framework; (2) in the usage of evidence-based knowledge graph, it is an application of knowledge graph in carrying out system evidence-based analysis. The advantage of knowledge graph provides convenience in storage of the result of systematic analysis, as well as optimization of our achievement through cooperation. Our knowledge graph can be available to decision supporters to obtain reliable evidence from empirical studies, aiding them to carry out travel behavior interventions more wisely. On the other hand, our knowledge graph can also be available to other researchers, which enables optimization and expansion of our achievement, just as some evidence-based knowledge graph in the field of medicine do (Zhu et al., 2021).

The remainder of our study is arranged as follows. Section 2 shows how related empirical interventions are obtained. Detailed descriptions of ontology of evidence-based knowledge graph and its construction are presented in section 3. Section 4 is the result of systematic review concerning effectiveness and reliability, supporting the implementation of sustainable travel behavior interventions. Based on above sections, section 5 provides the contribution and future research directions of our study, while section 6 is the conclusion.

2. Selection of empirical analysis literature

As mentioned above, soft travel behavior interventions change participants' psychological cognition, thus changing their travel behavior in a softer way. According to related research, measures and targets of travel behavior interventions vary from off-peak travel to avoid congestion, carsharing to reduce car usage, and shared transportation to lessen car owning. In this research, we set sustainable travel as our target, carrying out evidence-based analysis of empirical studies on lowering travel carbon emissions. Thus, the principles of literature selection are listed as follows.

(1) Interventions studied in the literature must contain something soft to intervene travel behavior, i.e., not through hard restriction measures only. Combining hard restriction measures and soft interventions is accepted.
(2) Target of interventions in the literature should be sustainable travel related, ultimately lowering traffic carbon emissions. Besides mentioning traffic carbon emissions directly, indirect targets including reducing individual motorized mileages, increasing proportion of collective travel, promoting active travel are all acceptable. However, strategies not focusing on travel behavior such as replacing internal combustion engine (ICE) vehicles with electric vehicles do not meet our requirement.
(3) Studies in the literature should be empirical studies, showing differences of travel behavior before and after the implementation of interventions. Real effect of interventions to travel behavior is necessary. Travel behavior surveys or models analyzing participants' attitudes towards interventions are not receivable due to the failure in reflecting real effect of the interventions.

Based on these principles, we collated relevant literature about empirical studies worldwide including both first-hand research articles and related reviews. For first-hand research articles, keywords include “personalized mobility management” or “personalized travel management”, “sustainable travel” or “low carbon travel”, “voluntary travel behavior change”, “travel incentive” and “carbon incentive”, while all articles should be empirical studies. For reviews, besides searching for keywords above, we achieved more reviews from references from research articles, thus enabling iterative searching. The database we used included Elsevier and Google

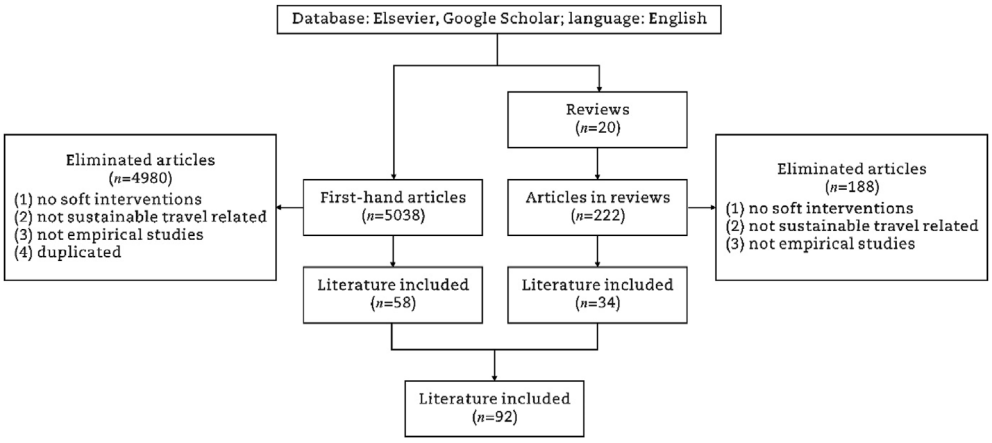

Fig. 1 – Literature selection process.

Scholar, while the language of the literature, or at least the abstract, must be English.

5038 research articles and 20 reviews (including 222 research articles) met the searching strategy. Based on above selection principles, 34 out of 222 research articles from reviews were acceptable, while 58 out of 5038 first-hand research articles reached our requirement after duplication check. The whole selection process can be illustrated as Fig. 1.

3. Construction of evidence-based knowledge graph

3.1. *Data structure of evidence-based knowledge graph*

The core of knowledge graph data structure is sets of entities and relations, i.e., the ontology of knowledge graph. For evidence-based knowledge graph, core entities include reliability of evidence, intervention practice and design of intervention studies. Our task is to obtain elements mentioned above from literature, thus building evidence-based knowledge graph from bottom to top. Data structure of evidence-based knowledge graph is as Table 1.

Entities and relations in Table 1 are converted into knowledge graph for storage in graph database Neo4J, as illustrated in Fig. 2. Main entity in Table 1 is the central node

Fig. 2 – Storing of evidence-based knowledge graph.

in Fig. 2, which is surrounded by other entities. Main entity and other entities are connected by relations in Table 1. The knowledge graph is publicly assessable at http://47.100.202.

Table 1 – Data structure of evidence-based knowledge graph.

	Type of entities	Name of relation	Examples of entity
Main entity	Number of evidence	–	E0020
Reliability of evidence	Evidence hierarchy	Inter_Category	Random controlled trials, semi-experiment, experiment with no comparison
	Risk of bias	Inter_Bias	Random sequence generation bias, allocation concealment bias
	Evidence assessment	Inter_GRADE	High, moderate, low, very low
Intervention practice	Intervention types	Inter_BelongTo	Goals and planning, feedback and monitoring
	Intervention targets	Inter_Target	Car proportion, carbon emission
	Intervention outcomes	Inter_Outcome	Change in household travel patterns; total carbon emissions decreased by 10%
Design of intervention studies	Region	Inter_Region	London, Xuzhou, Ghent
	Kinds of participants	Inter_Participant	People, households, schools
	Scenario	Inter_Scenario	Workplace interventions, school interventions, Unspecified interventions

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3.2. *Illustration of evidence-based knowledge graph elements*

In data structure expressed in Table 1, all entities and corresponding relations can reflect characteristics of evidence from empirical analysis.

3.2.1. *Reliability of evidence*

In terms of reliability of evidence, critical entities include evidence hierarchy, risk of bias and evidence assessment grading.

Evidence hierarchy is critical in evidence-based practice, reflecting reliability of evidence. The more reliable the implementation process of experiments, the more reliable the evidence can be obtained, which should be adopted first. On the contrary, evidence obtained from unreliable experiment can hardly be replicated, thus bringing its reliability into question, so that it should not be preferred in practice. Evidence in different levels of evidence hierarchy has different reliability, which can be classified in descending order of reliability as: systematic review with full volume of reliable random controlled trials, random controlled trials with sufficient quantities of participants (RCT), quasi-experiment with no randomization, experiment with no comparison group, expert views, etc. Based on common practice in evidence-based practice, evidence which is sufficiently reliable should be systematic review or RCT. However, due to lack of unified evidence reliability principles and insufficient amount of RCTs carried out in the field of travel behavior interventions, levels of evidence hierarchy in our study include RCT, quasi-experiment and experiment with no comparison.

Risk of bias describes the possibility of producing bias throughout the whole process, such as study design, intervention implementation and result analysis. It is the key indicator in evidence assessment. Based on a report from Cochrane Collaboration (Higgins et al., 2019), an authoritative academic institution in the field of evidence-based medicine, risk of bias can be described as Table 2 shows. The less the risk of bias, the higher the evidence can be graded, meaning that corresponding result is more reliable. Evidence hierarchy and risk of bias are the foundation of evidence assessment.

Table 2 – Risk of bias classification and analysis methods.

Bias	Analysis method
Selection bias	Random sequence generation. Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups. Allocation concealment. Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen in advance of, or during, enrolment.
Performance bias	Blinding of participants and personnel. Describe all measures used to blind study participants and personnel from knowledge of which intervention a participant received.
Detection bias	Blinding of outcome assessment. Describe all measures used to blind outcome assessors from knowledge of which intervention a participant received.
Attrition bias	Incomplete outcome data. Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group, reasons for attrition or exclusions where reported, and any re-inclusions in analyses performed by the review authors.
Reporting bias	Selective reporting. State how the possibility of selective outcome reporting was examined by the review authors, and what was found.
Other bias	Other sources of bias. State any important concerns about bias not addressed in the other domains in the tool.

Evidence assessment, taking other characteristics into consideration besides evidence hierarchy and risk of bias, assesses reliability of evidence thoroughly. Based on the report from Cochrane Collaboration (Higgins et al., 2019), evidence assessment is carried out by grading of recommendations assessment, development and evaluation (GRADE). GRADE classifies evidence into four levels based on its reliability: high, moderate, low and very low. For RCT evidence, its reliability is higher than non-randomized trials by its nature, thus basic level of RCT evidence is "high" level. Oppositely, for non-randomized trial evidence, namely confounding and selection bias, due to lack of randomization process, non-randomized trial evidence is two levels lower than RCT evidence, rated as "low" level. Basic level should be adjusted to get the ultimate assessment result of the evidence, both upwards and downwards, based on other characteristics of evidence. If evidence is obtained from study with high risk of bias, with inexplainable inconsistent result in different studies, with indirect comparison between different interventions or additional restrictions for participants or scenarios, with insufficient size of participants or with no report on insignificant result, its level should be downgraded by one level. On the other hand, if evidence is obtained from non-randomized study producing large, consistent and precise effects, with clear association between dose of the intervention and effect size, or with negative bias that may underestimate the effect, its level should correspondingly be upgraded by one level. In the field of evidence-based medicine, Popp et al. (2021) mentioned about the process of evidence assessment in terms of treatment effect of

antibiotics against COVID-19 using GRADE system, while in the field of urban transportation, Carlin et al. sorted out risk of bias of some studies about interventions to promote walking work (Carlin et al., 2016).

3.2.2. *Intervention practice*

As for intervention practice, related entities include intervention types, intervention targets and intervention outcomes.

In terms of intervention types, we referred Behavior Change Technique Taxonomy Version 1 framework (BCT) developed by Medical Research Council (Michie et al., 2013). The development of BCT collected ideas from experts from various fields including health, psychology and cognitive behavior. BCT divided medical interventions into 16 clusters and 93 sub-clusters.

Although BCT is designed for medical interventions, it can also be applied to other fields. For instance, Carlin et al. (2016) applied BCT into classification of interventions promoting walking to school for children and adolescents, proving BCT framework to be universal in classification of interventions. However, as a medical intervention classification method, direct migration of BCT to other fields has shortcomings. Carlin et al. (2016) found out that only some intervention types are mentioned in travel behavior intervention studies, while most of clusters have not been used. Therefore, based on 92 literatures, we integrated and summarized BCT framework into 8 major clusters and 22 minor clusters. Our classification method tried to strike a balance between precision in classification and convenience in using, providing a basis for decision supporters to decide application of interventions.

Goals and planning interventions work by providing participants with goals and plannings of sustainable travel, thus leading participants to switch to and stay in sustainable travel mode. Feedback and monitoring interventions offer feedback of sustainable travel related indicator to participants, informing participants with their sustainable travel behavior from detailed data. Knowledge incentive interventions provide participants with sustainable travel related knowledge, thus enabling participants to have further knowledge of sustainable travel. With comprehensive knowledge, participants can strengthen their sustainable travel behavior. Comparison of behavior interventions compare participants' sustainable behavior with other people to motivate them not to be left behind. In reward and threat type of interventions, participants are motivated by positive reward and negative threat to choose sustainable travel mode. Antecedents interventions change physical environment or add objects to the environment by improving sustainable travel facilities and offering free transit pass to attract participants to choose sustainable travel mode.

Besides clusters mentioned above, two minor clusters are introduced either. In habit formation interventions, participants cultivate habit of sustainable travel behavior and enhance it through implementation, while in social support interventions, participants choose sustainable travel mode under the help from other social forces.

Entities of intervention targets vary from different empirical analyses, including lowering travel carbon emissions, changing travel patterns, reducing car using proportion, increasing transit proportion, increasing walking proportion, increasing biking proportion, and some other goals. Correspondingly, entities of intervention outcomes report implementation result quantitatively.

With these entities, decision supporters are provided with theoretical basis of the effect of different types of interventions, thus enabling them to carry out evidence-based analysis based on current empirical literature.

3.2.3. *Design of intervention studies*

In the aspect of intervention studies design, related entities include study region, types of participants and study scenario. Entity of study region should be taken into consideration due to the difference between evidence-based transportation and evidence-based medicine. Evidence-based transportation lacks universality, meaning that effect of transportation interventions differs according to size and population of the region. Therefore, entity of study region should be contained in the knowledge graph. Kinds of participants include person, household and school, which should be recorded in the entity of participant. As for study scenario, the effect of same interventions under different scenarios varies, while different types of interventions may have different advantages under different scenarios, either. Study scenario entities are thus necessary for inclusion in the knowledge graph, taking values from school interventions, workplace interventions and interventions under unspecified scenarios.

3.3. *Summary*

In this section, we discussed about methods for construction of evidence-based literature knowledge graph concerning travel behavior interventions. Learnt from evidence-based medicine, we built the concept model for evidence-based transportation knowledge graph, including evidence reliability assessment, intervention practice methods and design of intervention studies (Fig. 3). This section set a foundation for the following section of evidence-based analysis and review.

4. Evidence-based analysis of sustainable travel behavior interventions

We carried out analysis based on evidence-based knowledge graph obtained from the above process. From 92 literatures, there are 86 unique studies, which produces 86 pieces of evidence correspondingly. Firstly, we conducted general analysis. As shown in Fig. 4, in terms of level of reliability assessment, 24 pieces of evidence belong to high reliability level, while 25 moderate, 14 low and 23 very low. Overall, the reliability of all evidence is quite evenly distributed. A considerable proportion of evidence is reliable for guiding decision-making, while there is no denying that some evidence should be reconsidered before adoption as its low reliability indicates that the effect reported in the study may not be reached in reality. In regard of intervention scenarios, shown in Fig. 5, most studies, 58 out of 86, did not define a specified scenario for intervention implementation. 15

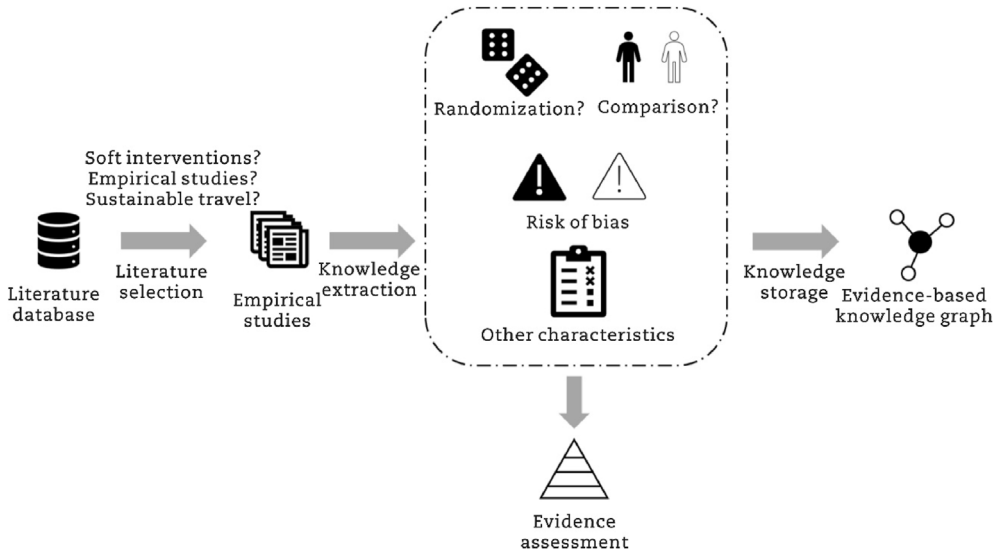

Fig. 3 – Construction of evidence-based transportation knowledge graph from empirical studies.

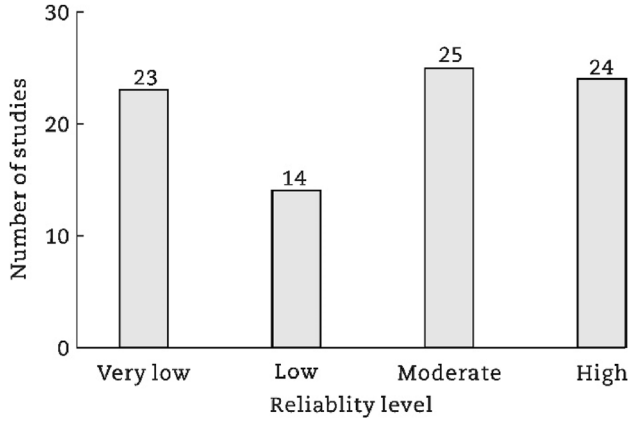

Fig. 4 – General distribution of study reliability levels.

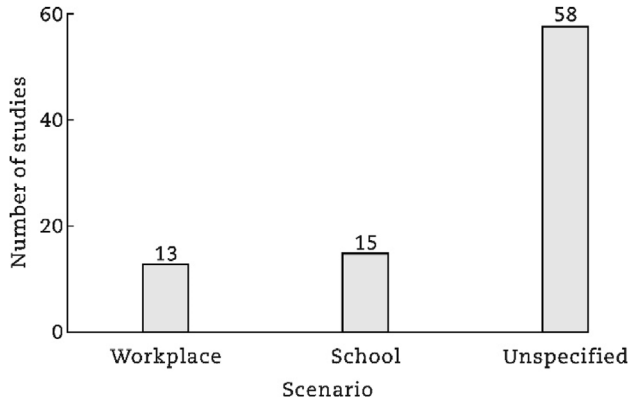

Fig. 5 – Distribution of study scenarios.

studies focused on school interventions while 13 studies on workplace interventions. As for types of interventions, goals and planning, antecedents, knowledge incentive and feedback and monitoring were adopted most frequently (Fig. 6). For intervention targets shown in Fig. 7, most studies

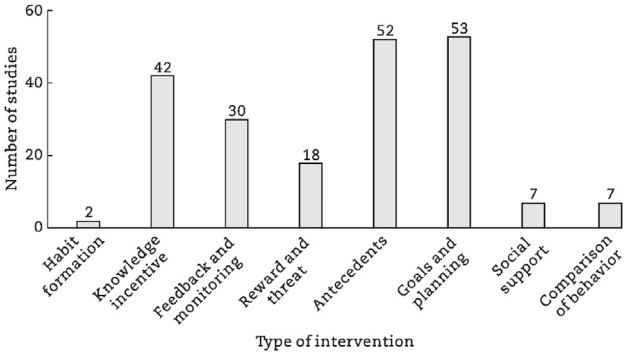

Fig. 6 – Distribution of types of interventions.

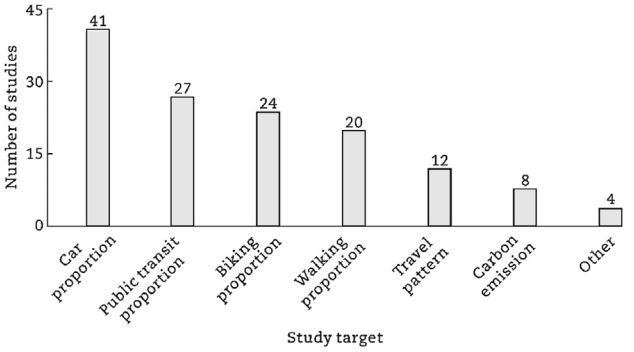

Fig. 7 – Distribution of study targets.

had a definite target, ranking decreasingly, changing car proportion, public transit proportion, biking proportion and walking proportion, rather than ambiguous target, altering travel pattern. Lowering carbon emission is the least adopted target.

Afterwards, we conducted detailed analysis according to the elements of the knowledge graph, i.e., scenarios, types of interventions and targets. As these elements vary, implementation of interventions varies, either. Decision supporters

can search for relevant evidence from the database using these elements accordingly for the design of interventions implementation in reality, showing the necessity of following detailed analysis.

4.1. *Analysis based on scenarios*

4.1.1. *Workplace interventions*

In some studies, the implementation scenario of the interventions was set to be workplace commuting, where the subject of the interventions was the participants' company. Therefore, the participants were homogeneous to some extent, while the same scenario also enabled the effect of interventions to be horizontally comparable. Key elements of every study are provided in Appendix Table A1 in affiliated material. 12 pieces of studies out of 13 showed the effect that participants changed their sustainable travel behavior after interventions to varying degrees, with detailed effect of lowering personalized travel mileage or increasing public transit, biking or walking proportion, which in turn lowered transport carbon emission.

However, one study among 13 studies showed different result that neither personalized travel related information incentive nor free transit pass was significant in changing employees' sustainable travel behavior (Tørnblad et al., 2014). The possible reason was that local public transit service was satisfying enough, and therefore new interventions failed in increasing participants' attitude towards public transit service. It indicated that besides intervention itself, the effect of intervention is related to external factors, such as intervention region, as well.

Among workplace interventions, antecedents were the mostly used type of interventions, adopted by 9 pieces of evidence. Main sub-types involved adding objects to the environment, in detail, providing participants with public transit timetables and public transit and biking maps. Other frequently used type was goals and planning, realized by action planning, offering personalized travel information and aiding participants to design action plans.

As for reliability levels, 2 out of 13 pieces of workplace interventions belong to high reliability level, while 4 moderate, 3 low and 4 very low.

4.1.2. *School interventions*

Some studies set their scenarios as school commuting interventions. For university students, their travel characteristics are converging with employees, therefore some studies involved interventions concerning reduction of car usage. However, their travel characteristics are not exactly the same. For students from elementary or middle schools, they cannot drive their own cars, but their parents may drive their cars to carry them to commute. Besides, as the commuting distance of students of elementary or middle schools is relatively short, some studies focused on guiding them to commute by bike or on foot, lowering carbon emission and enhancing physical activity at the same time. These characteristics all showed necessity to separate school interventions as an independent scenario. Key elements of every study are listed in Appendix Table A2 in affiliated material. Most studies proved the effectiveness of the interventions in changing participants' sustainable travel behavior, while a few studies found no effect (Gutierrez et al., 2014).

One of the features in school interventions for students from elementary schools is Walk School Bus. In Walk School Bus, staff from the school lead students to walk to go to school. This kind of intervention belongs to habit formation, helping students to form the habit to walk to school. From empirical studies, this kind of intervention succeeded in guiding students to walk to school, reducing not only themselves but also their families' car usage mileage, achieving student-led family sustainable travel behavior promotion and carbon emission reduction (Mendoza et al., 2009, 2011).

In terms of reliability levels, 5 out of 15 pieces of school interventions evidence belong to high reliability, while 4 moderate, 3 low and 3 very low.

4.1.3. *Unspecified interventions*

Other studies did not set specified scenario. In these studies, interventions tried to affect daily travel. Key elements of the studies are reported in Appendix Table A3 in affiliated material. Different from workplace interventions and school interventions where interventions could be carried out uniformly, among unspecified interventions, participants came from different groups of people. Therefore, the variety of interventions used in the different studies was relatively large. Similarly, a few studies reported insignificant effects of interventions (Eriksson et al., 2008; Gabrielli et al., 2014; Garvill et al., 2003; McMinn et al., 2012; Pronello et al., 2017; Tertoolen et al., 1998).

Some of the studies focused on combining hard measures, such as the opening of the metro operation, with soft measures, such as providing metro related travel information to maximize the effect of hard measures in altering sustainable travel behavior. These interventions belong to restructuring the physical environment (Meloni et al., 2017; Piras et al., 2018). Some studies classified participants into groups, showing that same intervention had different effect to different groups of people (Skarin et al., 2019).

Concerning reliability levels, among 58 pieces of unspecified evidence, 17 belongs to high reliability level, while 17 moderate, 8 low and 6 very low.

4.1.4. *Summary*

Distribution of types of interventions categorized by scenario is illustrated in Fig. 8. For workplace interventions, antecedents, along with goals and planning, are two mostly adopted types of interventions, both of them making up more than 25% of all studies. Reward and threat, and knowledge incentive have a relatively high proportion, as well. For school interventions, antecedents and knowledge incentive have the largest share, more than 20%, while goals and planning occupies a comparatively large proportion, too. For unspecified interventions, goals and planning and antecedents rank highest, occupying more than 20%, while knowledge incentive and feedback and monitoring types of interventions practiced quite frequently, as well. In summary, for all scenarios, most frequently implemented types of interventions are antecedents, goals and planning, and knowledge incentive.

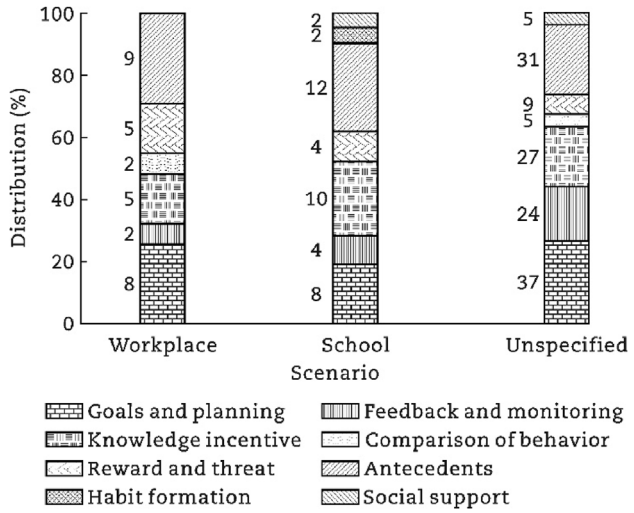

Fig. 8 – Distribution of types of interventions categorized by scenario.

For types of interventions less frequently adopted, habit formation interventions were implemented only in school interventions via Walk School Bus, helping students to form the habit to walk or cycle to school. Social support interventions were used in school interventions and unspecified interventions, while no usage in workplace interventions were reported, indicating that social support interventions were not available in workplace interventions. Correspondingly, comparison of behavior interventions had no application in school interventions.

In terms of reliability levels, distribution categorized by scenarios is reported in Fig. 9. The most reliable intervention scenario is school interventions, where evidence with high reliability accounts for more than 30%. The reliability of unspecified interventions is lower, while workplace interventions is the least reliable. Possible reason for this phenomenon may be that school interventions can be carried out by schools more conveniently, while interventions under other scenarios are more difficult to conduct.

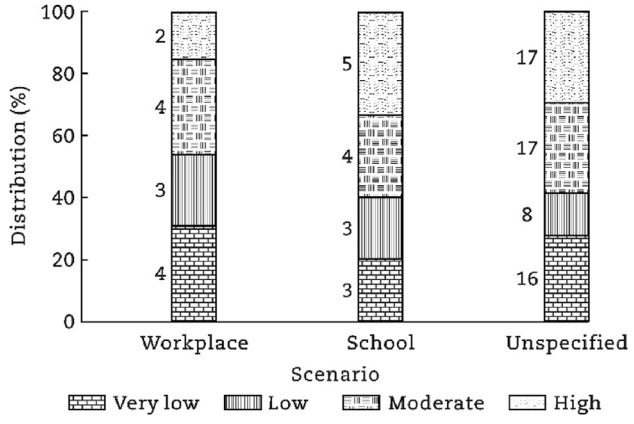

Fig. 9 – Distribution of reliability level categorized by scenario.

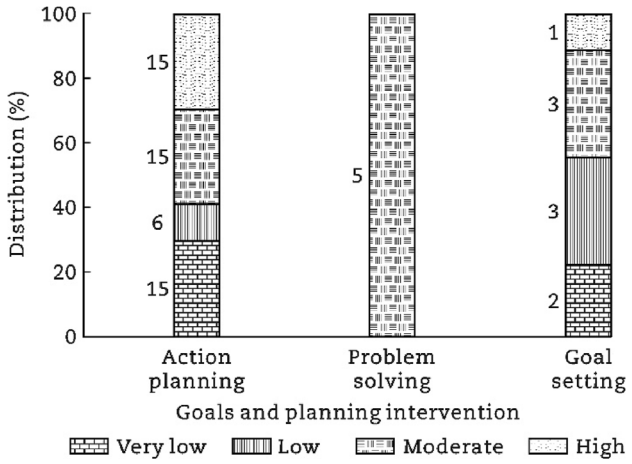

Fig. 10 – Distribution of reliability level of goals and planning interventions.

4.2. *Analysis based on types of interventions*

4.2.1. *Goals and planning*

For action planning, one of three sub-types in goals and planning interventions, main implementation method is to raise improvement plans on reducing travel carbon emission or other sustainable travel behavior related indicators based on participants' previous travel behavior (Ahmed et al., 2020). This type of intervention featured in providing personalized travel plans according to participants' own characteristics. Therefore, action planning works not only in regulating main factors influencing participants' sustainable travel behavior so as to realize the effect with a lower cost, but also in enhancing acceptability of participants to the plans, enabling broader use of the interventions.

For goal setting interventions, related studies achieved their targets by asking participants to set goals on sustainable travel behavior, and providing them with the difference between their current behavior and the goal, thus motivating them to reach their sustainable travel behavior goal (Gabrielli and Maimone, 2013a, 2013b).

A few studies chose to combine action planning interventions with coping planning interventions (or problem solving), listing possible obstacles participants may face when trying to switch to sustainable travel behaviors. In this way, participants can recognize what obstacle is the largest one for themselves to travel sustainably, and therefore they are guided to overcome them. Compared with only action planning, this type of interventions performed better (Hsieh et al., 2017, 2019).

After evidence assessment, we can draw the conclusion that among goals and planning interventions, 15 pieces of evidence have high reliability, while 15 have moderate reliability. 7 pieces are low in reliability, and other 16 can hardly be trusted. For reliability distribution of sub-types illustrated in Fig. 10, action planning interventions perform best; second come goal setting interventions. Despite the small sample size and lack of high reliability evidence, all 5 pieces of evidence of problem solving interventions belong to moderate category,

showing relatively acceptable reliability of problem solving interventions.

4.2.2. *Feedback and monitoring*

Main implementation method of feedback and monitoring interventions is through self-monitoring of behavior with feedback. Studies using this sub-type of intervention provided participants with their sustainable travel characteristics and related indicators such as energy consumption, physical activity amount and travel carbon emission for participants to self-monitor their sustainable travel behavior (Jariyasunant et al., 2015). Aside from this sub-type of interventions, some studies combined other types of interventions such as goals and planning to realize further sustainable travel behavior incentive.

Other feedback and monitoring interventions include self-monitoring of behavior without feedback and monitoring of others' behavior. These two sub-types of interventions only focus on monitoring themselves or other people's behavior without feedback and try to affect participants' sustainable travel behavior via their self-awareness (Hemmingsson et al., 2009). This differs these two sub-types of interventions from self-monitoring of behavior with feedback.

For evidence assessment of feedback and monitoring related empirical studies, 6 out of 30 pieces of studies are highly reliable, while 7 moderate pieces, 4 low pieces and 13 very low, which is a generally unsatisfactory distribution. Detailed distribution of evidence reliability is illustrated in Fig. 11. Self-monitoring of behavior with feedback accounted for a quite large proportion of all studies, while only 20% belongs to high or moderate reliable clusters. For interventions monitoring of others' behavior, both 2 pieces of evidence have moderate reliability.

4.2.3. *Knowledge incentive*

Among knowledge incentive interventions, sub-type named shaping knowledge aims to inform participants of how to perform sustainable travel behavior. Main form of implementation is through providing maps or other information to guide participants to choose sustainable travel behavior.

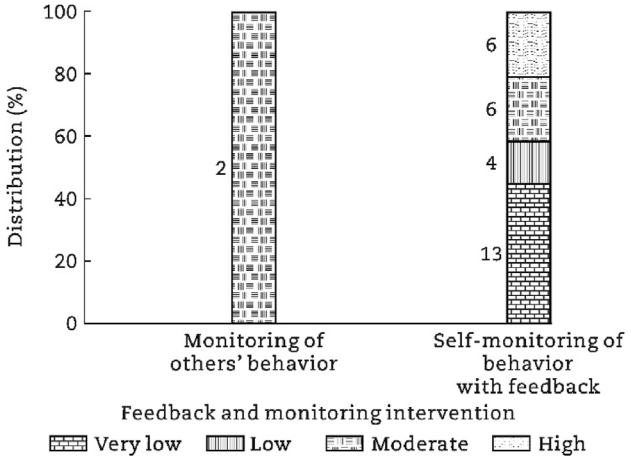

Fig. 11 – Distribution of reliability level of feedback and monitoring interventions.

One of the reasons for people to choose private vehicles as main travel pattern is because they know little about how to travel by public transit and other sustainable travel behavior. If they are informed of related information, that public transit and other travel patterns can satisfy their travel needs and that utility of these patterns is comparable to private vehicles, they may change their travel behavior, therefore following the guide to choose sustainable travel behavior. Shaping knowledge can be implemented through providing personalized information for newly operated transit line to guide people to change their travel pattern (Meloni et al., 2017; Piras et al., 2018), offering multi-dimensional indicators of different available routes via navigation software (Sottile et al., 2021), informing students and employees of community cycling, bus or facility maps and timetables to aware them of the convenience of other travel patterns (McKee et al., 2007; Mutrie et al., 2002; Petrunoff et al., 2015; Wen et al., 2008), while the ultimate goal of shaping knowledge is to eliminate information asymmetry.

In information about health consequences interventions related studies, participants receive knowledge about how changing travel patterns will affect their health, which in turn affects their utility among different travel patterns, and eventually affects their travel behavior. Target for this type of interventions is mainly to promote walking and cycling, while main implementation form is through doctor's advice (Arroyo et al., 2018; Hemmingsson et al., 2009) and lectures at school or workplace (Aittasalo et al., 2012; Geng et al., 2016; Nielsen and Haustein, 2019).

Interventions belonging to information about social and environmental consequences are implemented through information regarding how public transit, cycling and walking can lower carbon emission, how private vehicle can increase carbon emission, and how carbon emission affect global warming so as to raise their environmental responsibility and thus change their travel patterns (Ahmed et al., 2020; Geng et al., 2016; Olsson et al., 2021; Piras et al., 2018; Tertoolen et al., 1998; Wen et al., 2008). This kind of intervention is usually implemented in a united way, which means information is not provided in personalized way. The lack of personalization may reduce its effect.

Only one study researched about the effect of information about emotional consequences. In this study, participants were classified into 3 groups: 1 group was given examples of how other people got fun through cycling, incentivized from social norm; 1 group was awarded a free bicycle, incentivized from finance; the other group received the information on how to protect the environment from cycling, incentivized from moral norms. The result of every incentive was compared to understand which incentive was the most effective (Olsson et al., 2021).

We can conclude from evidence reliability assessment that, among knowledge incentive interventions, 17 pieces of evidence are highly reliable, while 11 moderately and 6 lowly reliable, and 8 pieces should hardly be adopted. From detailed distribution (Fig. 12), we can get the conclusion that information about health consequences is the most reliable sub-type of interventions, with 60% pieces of evidence highly reliable and other 40% moderate. Possible reason for that phenomenon is that this sub-type of interventions is

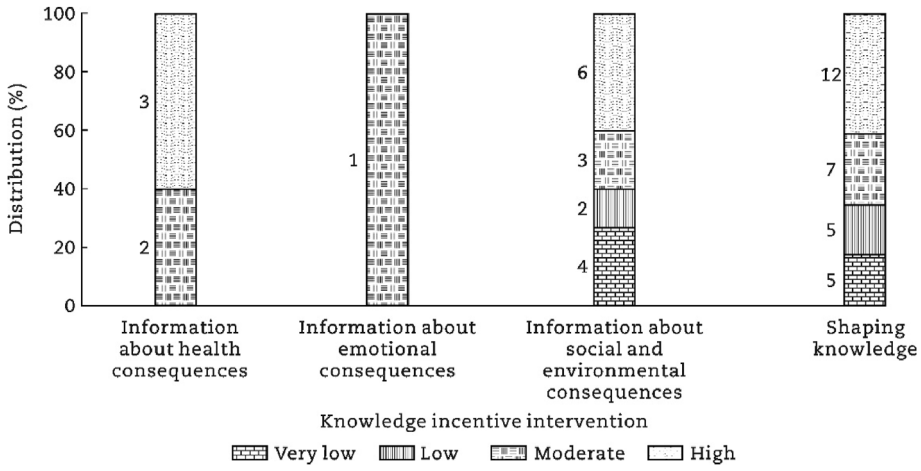

Fig. 12 – Distribution of reliability level of knowledge incentive interventions.

highly related to medical interventions in evidence-based medicine. Shaping knowledge and information about social and environmental consequences are two highly reliable sub-types, either, with both more than 40% of high reliable pieces of evidence and more than 60% of high and moderate. The only piece of evidence of information about emotional consequences is moderate in reliability.

4.2.4. *Comparison of behavior*

Comparison of behavior interventions were conducted through comparison of behaviors among different participants. Participants' multi-dimensional indicators such as travel time, travel costs, carbon emission, physical activity amount and energy consumption are compared to other people in their school, area or the whole country, so as to give them their situation of these indicators and to motivate them to outperform other people's behavior or outcomes, thus reaching the target to promote sustainable travel behavior (Jariyasunant et al., 2015).

Result of evidence assessment showed that among 7 studies using comparison of behavior interventions, no evidence with high reliability was produced, while 3 belong to moderate, 1 belongs to low and other 3 are all very low reliable, indicating low quality in this type of interventions.

4.2.5. *Reward and threat*

Reward and threat interventions are effective in providing various kinds of reward, material or emotional, based on behavior or based on outcome, to participants to incentivize their sustainable travel behavior or providing punishment for unpromoted behavior. This type of interventions mainly focuses on reward and punishment for behavior or outcome which have already happened, not including financial incentives such as free transit pass.

In related empirical studies, material reward based on behavior was the most frequently used sub-type of intervention, rewarding participants focusing on the behavior of changing their travel behavior. As an instance, one study performed material reward based on participants' travel behavior in two cities and provided direct financial incentive or indirect financial incentive (coupons) in each city (Polydoropoulou et al., 2019; Tsirimpa et al., 2019). Some studies performed material reward based on outcome brought by behavior change, such as changes in carbon emission or physical activity amount, using these indicators to scale participants' behavior change incentivized by interventions, and thus provided material incentives based on changes of outcomes (Foxx and Schaeffer, 1981).

Aside from material reward, some studies focused on emotional reward, both based on behavior and outcome, incentivizing participants via reward besides material issues, such as environmental certificates based on saved carbon emission, with comparison between material reward and emotional reward (Minnich et al., 2021).

For reward alternative behavior interventions, its difference between pervious interventions is that it only incentivizes sustainable travel behavior, which means no incentive for private vehicles reduction, guiding sustainable travel behavior more explicitly (Bowden and Hellen, 2019; Castellanos, 2016; Cooper, 2007; de Kruijf et al., 2018; Di Dio et al., 2015, 2018, 2020; Minnich et al., 2021; Polydoropoulou et al., 2019; Tsirimpa et al., 2019).

Besides positive reward, some studies researched the effect of negative punishment, such as charging for private vehicle usage, in promoting sustainable travel behavior (Jakobsson et al., 2002).

Conclusions from evidence assessment showed that 1 high reliability, 5 moderate, 4 low and 8 very low pieces of evidence made up all evidence from reward and threat interventions. Relatively low reliability may come from the small participant size of reward and threat interventions, due to the characteristics of financial incentive. Detailed reliability distribution is illustrated in Fig. 13. The only highly reliable evidence was carried out through material reward based on behavior and reward alternative behavior, while these two interventions also suffered from low reliability for more than 70% evidence with very low reliability, showing the necessity to improve the reliability of reward and threat interventions.

4.2.6. *Antecedents*

Antecedents focus on interventions that change physical and social environment conditions to influence participants'

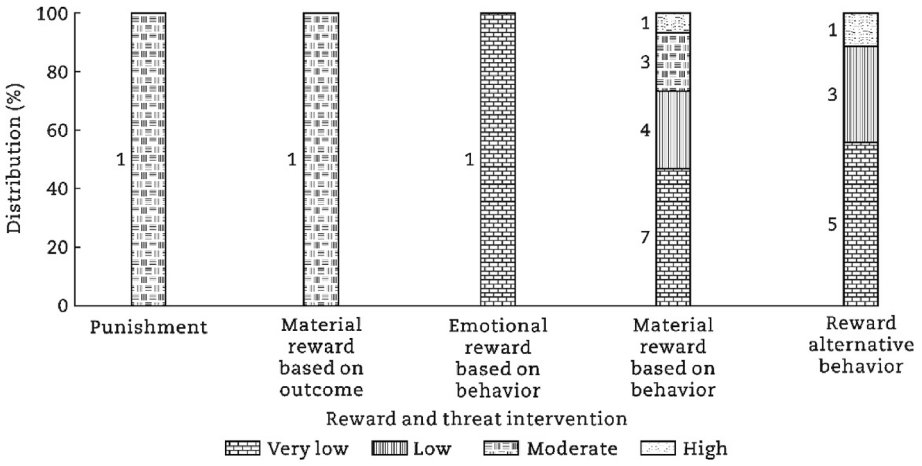

Fig. 13 – Distribution of reliability level of reward and threat interventions.

environmental perceptions, and therefore change their travel behavior. Among antecedents studies, most frequently covered sub-types include restructuring the physical environment and adding objects to the environment.

In restructuring the physical environment interventions, main scenarios were commuting, both school and workplace, by changing physical infrastructure such as cycling and pedestrian paths next to schools and workplaces or setting up shower room or garages for cycling to enhance the safety and convenience for cycling, so as to attract more participants to commute by bike or on foot (Brockman and Fox, 2011; Buliung et al., 2011; Mammen et al., 2014a, 2014b; McDonald et al., 2013, 2014; McDonald et al., 2013; O'Fallon, 2010).

Adding objects to the environment interventions is one of the most frequently used sub-types. Some studies provided discount transit pass for participants to guide them to try traveling by public transit, changing their opinion on public transit and making a new choice of travel mode (Abou-Zeid and Ben-Akiva, 2012; Abou-Zeid and Fujii, 2016; Bamberg, 2006; Bamberg and Rees, 2017; Fujii and Kitamura, 2003; Haq et al., 2008; Matthies et al., 2006; Skarin et al., 2019; Thøgersen, 2009; Tørnblad et al., 2014). Additionally, some studies offer public transit maps and timetables as information aid for participants to transfer to public transit traveling (Bamberg, 2006; Bamberg and Rees, 2017; Gärling et al., 1998; Tertoolen et al., 1998; Wen et al., 2008).

Besides these two interventions, a few studies implemented interventions by reducing exposure to cues for behavior. These studies restricted private vehicle usage to realize the target to guide participants to use sustainable travel behavior. An example study compared the effect of interventions in two comparable hospitals, one only through promotion interventions of sustainable travel behavior, one with parking restrictions and increasing parking fees, reflecting the effect of interventions aiming to reducing exposure to negative issues (Petrunoff et al., 2015).

From evidence assessment, antecedents interventions consisted of 16 pieces of evidence with high reliability, 12 moderate, 8 low and 16 very low. We can find out detailed

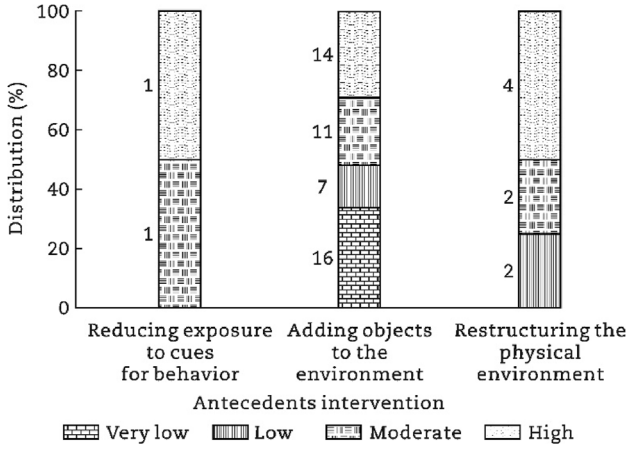

Fig. 14 – Distribution of reliability level of antecedents interventions.

distribution in Fig. 14. Despite the small amount of reducing exposures to cues for behavior and restructuring the physical environment evidence, they have a relatively high reliability, with 50% of evidence were rated as highly reliable. On the contrary, large amount of adding objects to the environment evidence cannot ensure a satisfactory proportion of reliable evidence.

4.2.7. *Habit formation*

For habit formation interventions, main implementation method is to organize staff of schools to lead students to walk to and from school, enhancing students and their parents' perception of safety, thus cultivating students' habit to walk instead of taking cars, or so-called "walk school bus" in American and Canadian schools. Some research studied "walk school bus" project in various places, organizing school staff to take students walk to and from school multiple times in a week to form habits (Mendoza et al., 2009, 2011).

Based on evidence assessment, among habit formation interventions, 1 piece of evidence has high reliability, and 1 has moderate reliability.

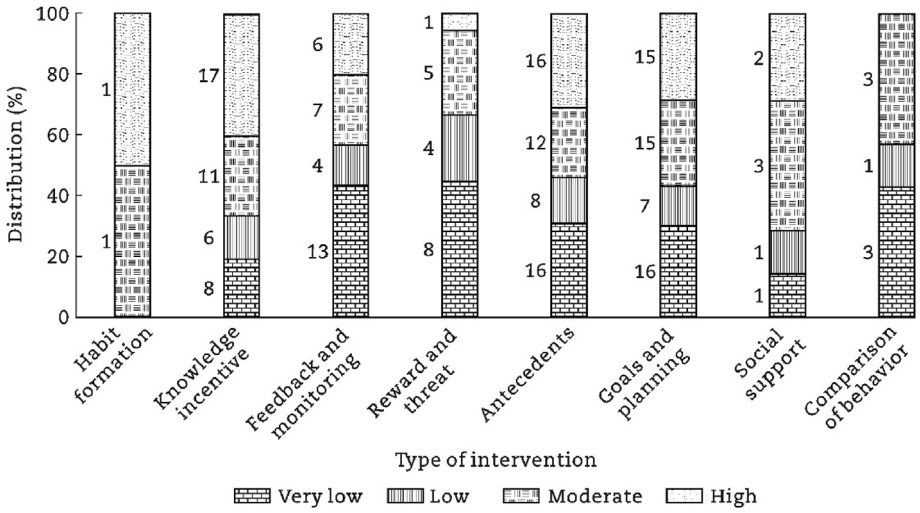

Fig. 15 – Distribution of reliability level of interventions categorized by types of interventions.

4.2.8. *Social support*

Social support interventions involve cooperation with other social organizations. Number of social support interventions is limited in our study. Main way of implementation was to cooperate with schools by organizing staff to guide students to walk to and from school. Some study expanded the study horizon from school commuting to daily travel, combining with biking lessons and free bikes for poor families (Thomas et al., 2009). Social support interventions have a high degree of overlap with habit formation interventions (Mendoza et al., 2009, 2011). However, two types of interventions focus on different perspectives, so it is necessary to separate these two types of interventions.

According to evidence assessment, evidence in social support interventions consists of 2 pieces of evidence with high reliability, 3 pieces moderate, 1 piece low and 1 piece very low.

4.2.9. *Summary*

Summary of reliability levels of different types of interventions is illustrated in Fig. 15. Excluding habit formation, social support and comparison of behavior with insufficient size of evidence, knowledge incentive type of interventions is the most reliable with more than 40% of high reliability evidence. This may be caused by the convenience of implementation, while its relationship with evidence-based medicine can also explain this phenomenon. Besides knowledge incentive, antecedents, along with goals and planning, are also relatively reliable types of interventions with more than 30% of high reliability evidence, owing to convenience in implementation, similarly. With only 20% of evidence belonging to high reliable category, there is still much room for improvement for feedback and monitoring type of interventions, while reward and threat type of interventions is the least reliable type due to difficulty in implementation of financial incentive.

4.3. *Analysis based on targets*

Evidence-based analysis based on intervention targets can guide decision supporters to decide which type of interventions and what detailed intervention measures to choose when facing different targets. Based on evidence-based analysis mentioned previously, intervention targets can be classified into altering travel patterns generally, changing one or more travel mode proportion, lowering transport carbon emission and some other unclassified targets.

For studies facing different targets, main types of interventions implemented differ, either, shown in Fig. 16. In studies with target of changing definite travel mode proportion, distributions of mainly used types of interventions are similar. Most frequently used types included antecedents, goals and planning and knowledge incentive. Compared with studies targeting private vehicle proportion and public transit proportion, those targeting cycling proportion and walking proportion, or active travel proportion, studies using social support interventions had a larger share. As for studies targeting altering travel patterns generally, main types of interventions included goals and planning, feedback and monitoring and antecedents, while type of feedback and monitoring interventions had a significant larger share than studies with other definite targets. Regarding studies targeting travel carbon emission, main intervention types were goals and planning, and feedback and monitoring. This phenomenon is related to the quantifiability of carbon emission, as participants can be provided with carbon emission as the feedback of their sustainable travel behavior, and therefore they can design plans to reduce carbon emission, realizing the target of studies.

Distribution of evidence reliability level categorized by target is shown in Fig. 17. Studies with the target of public transit and walking proportion had the highest reliability, with 40% of the evidence belonged to high reliability, while studies targeting walking and cycling had the largest share of high and moderate reliability. On the opposite, changing travel patterns generally and lowering travel carbon emission were least reliable, with more than 60% of evidence belonging to low and very low category. This leads to the difficulty of adoption of these types of evidence, which is resulted by the vagueness of the targets.

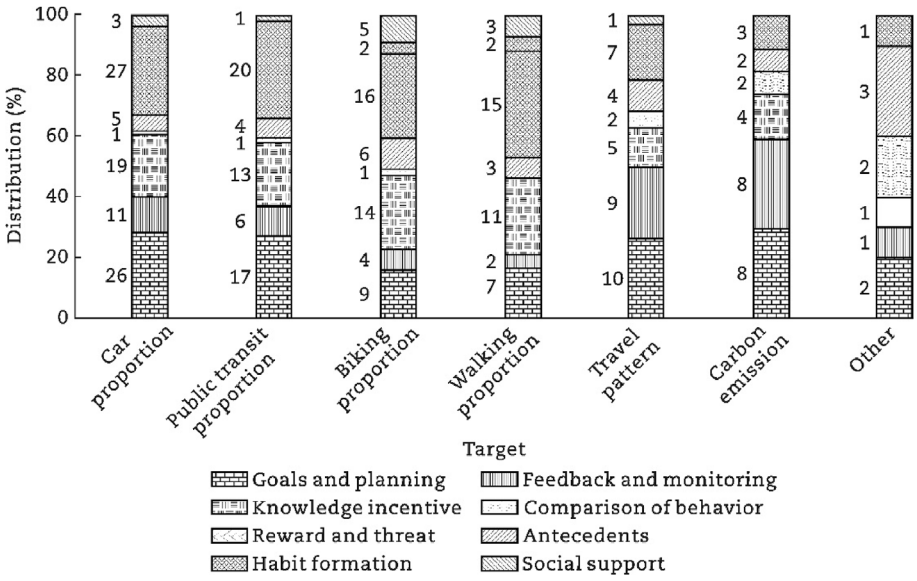

Fig. 16 – Distribution of types of interventions categorized by target.

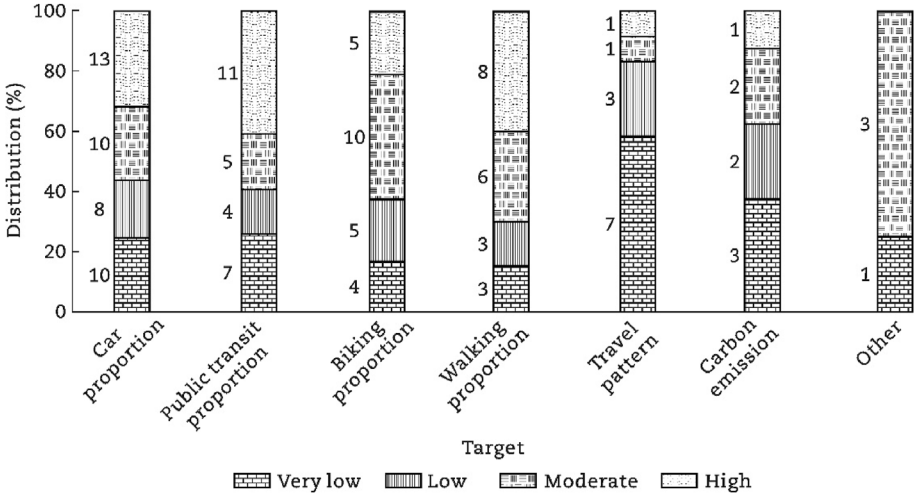

Fig. 17 – Distribution of reliability level categorized by target.

4.4. *Summary*

In this chapter, we conducted systematic analysis of types of interventions under different scenarios and for different targets. The distribution of types of interventions categorized by scenarios and targets, implying the applicability of intervention types, can guide decision supporters to design their intervention plans according to real scenario and target. Besides, this chapter offered evidence assessment from multi-dimensions of scenarios, types of interventions and targets in order to obtain the distribution of evidence from empirical studies to guide decision supporters to adopt evidence with the highest possible reliability and circumvent the result in evidence with low reliability.

From the analysis, several conclusions can be drawn. For interventions under every scenario, antecedents type of interventions all accounts for the largest proportion, while goals and planning, along with knowledge incentive, both have a relatively large proportion, either. In workplace interventions, reward and threat type of interventions have a relatively high share; in school interventions, reward and threat, and feedback and monitoring are two frequently implemented types, while for interventions under unspecified scenarios, goals and planning is one of the main types of intervention. Regarding distribution of level of reliability categorized by scenario, unspecified interventions and school interventions both have a relatively larger proportion of highly reliable evidence than workplace interventions, while unspecified scenario interventions are more reliable with a larger proportion of high and moderate reliable evidence. Concerning distribution of level of reliability categorized by intervention type, excluding habit formation, social support and comparison of behavior which have a limit size of samples, knowledge incentive is the most reliable type of interventions. Antecedents and goals and planning had a relatively high reliability, while the reliability of feedback and monitoring type of intervention was

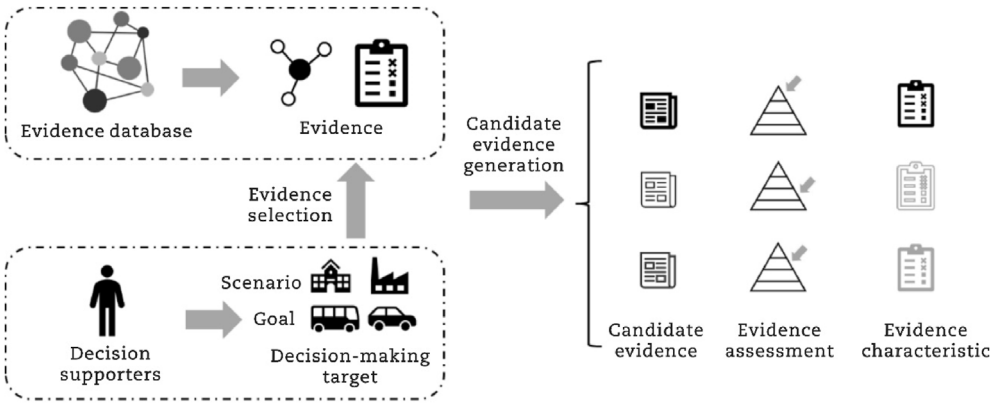

Fig. 18 – Application of evidence-based knowledge graph in travel behavior intervention decision-making.

unsatisfactory. Reward and threat is the type of interventions with the least reliability. In terms of target categorization, among those with definite transport mode target, antecedents are all widely used, and knowledge incentive and goals and planning are both frequently implemented, either. For those changing travel patterns generally, goals and planning and feedback and monitoring are two most frequently deployed types of interventions. According to evidence assessment, among interventions affecting definite transport mode, interventions targeting public transit and walking have a relatively large proportion of highly reliable evidence, while interventions targeting private vehicle and cycling are unsatisfactory. Interventions affecting travel patterns generally and lowering travel carbon emission are the least reliable targets.

In summary, this section provides the effectiveness and reliability result of systematic review of studies categorized by scenarios, types of interventions and targets, providing decision supporters with theoretical aid for designing sustainable travel behavior interventions in reality. Our study offers an option to address the lack of universality of travel behavior interventions, or even in the entire field of urban transportation.

5. Discussions and research prospects

Concepts of evidence-based practice, applied in evidence-based medicine, enables medical decision supporters to assess full volume of current evidence, instead of simple experience and case studies only, and accept most reliable evidence. With these advantages, reliability, objectivity, and precision of evidence-based decision-making can be promoted. Similarly, when applied to the field of urban transportation, concepts of evidence-based practice can mitigate the lack of objectivity in urban transportation decision-making. Taking sustainable travel behavior intervention as a pioneering example, we carried out an evidence-based assessment on full volume of current empirical studies and analyzed the reliability and validity of the studies categorized by scenarios, types of interventions and targets. Therefore, decision supporters can make more objective use of evidence so as to implement sustainable travel behavior interventions better, compared with implementing only according to their experience or case studies.

As for the usage of knowledge graph, its high extensivity and integrability enables cooperation optimization and extension of evidence-based database in the future by making our achievement available to other researchers. Besides, in terms of data organization, knowledge graph outperforms traditional database in storing elements with strong relational characteristics, suitable for storing elements of evidence. Graph related algorithms, correspondingly, can help decision supporters match evidence in the database. These advantages can well explain the reason why we adopted knowledge graph as the way of evidence data organization.

An example of application of our framework is illustrated in Fig. 18. Decision supporters can search for evidence from the database using graph related or other algorithms according to scenarios or targets necessary for implementation. Searching result contains reliability, validity, and other characteristics of evidence, according to which decision supporters can select suitable evidence to carry out in reality, realizing evidence-based decision-making with a higher reliability. This proves the feasibility of evidence-based knowledge graph framework for decision-making and the necessity to introduce concepts of evidence-based practice into the field of urban transportation. Take an example in which scenario is school intervention, target is to lower car usage proportion, while decision supporters value only high or moderate level of evidence as reliable. These characteristics form the criteria for searching evidence from the database, yielding result as Fig. 19 shows. Two pieces of intervention evidence meet the needs (E0510 and E0780), whose types of interventions, detailed interventions, outcomes and other characteristics are also illustrated for reference for decision supporters to develop intervention plans in reality.

Based on the result of the above systematic review, some directions for future research can be obtained to optimize empirical research of sustainable travel behavior interventions.

First, in the hierarchy of methodology, a unified implementation and assessment framework concerning concepts of evidence-based practice is necessary for consideration. Currently, there is no unified evidence-based framework for

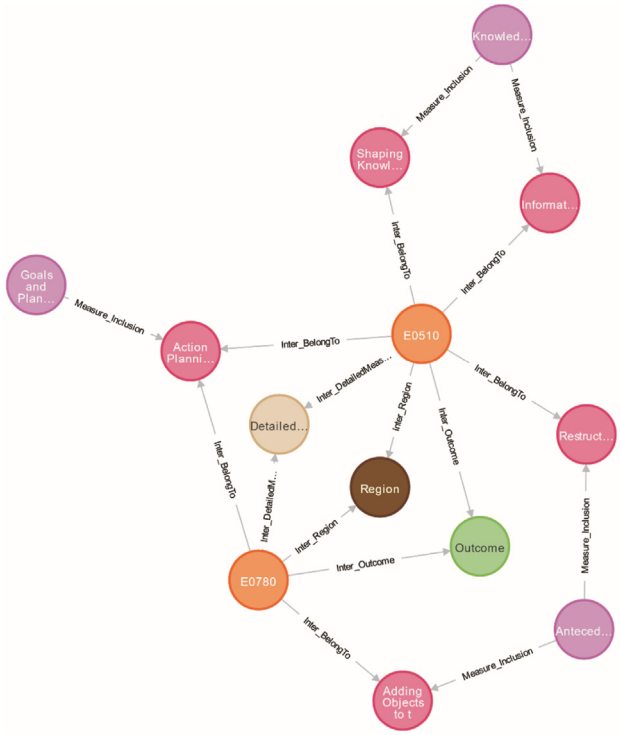

Fig. 19 – Result of application of evidence-based knowledge graph example.

travel behavior intervention implementation. Just as evidence-based medicine, it is necessary to have a unified evidence-based framework with which the whole process of interventions, from design, implementation, result report to evaluation, are conducted with a unified standard. Currently, only a few studies follow this instruction, providing their main findings including purpose, characteristics of participants, methods, results, conclusions, etc., in a structured format in their abstracts (Mendoza et al., 2011; Merom et al., 2005). Not only does it regulate the way how evidence from empirical studies is produced, lowering subjectivity in the process of decision-making, but it also enables decision supporters or other researchers to have a better understanding of the result of the studies, thus easing the effort to construct systematic review so as to support the process of decision-making with best evidence.

Second, for individual empirical study itself, it would be more beneficial if researchers pay more attention to its design and implementation method. According to reliability evaluation method from Cochrane Collaboration implemented in our study (Higgins et al., 2019), studies with high risk of bias, inconsistency, indirectness or imprecision are evaluated as less reliable. Even if these empirical studies receive pleasing results, they are still evaluated as unreliable studies and will not be preferred by decision supporters. Our study showed that studies concerning interventions belonging to some specified categories, namely reward and threat, and feedback and monitoring, are relatively low in reliability. Thus, just as evidence-base medicine do, it would be better for researchers to lay sufficient emphasis on every step in the whole process of intervention implementation, especially for categories with relatively low reliability. It is necessary that the number of recruited participants to be sufficient, the assignment of participants to different groups to be randomized, participants and personnel to be blinded, and result of the studies to be reported unselectively. High reliability means result of the evidence worthy for reference for decision supporters, while evidence with low reliability is a waste of work.

Last, as for the implementation of interventions, there is also some place for optimization. Currently, most empirical studies implemented multiple types of interventions at the same time. A bunch of interventions makes it difficult to figure out which intervention is the critical one (Tørnblad et al., 2014), which also adds to the difficulties in systematic review, as it makes it incomparable among various implementation studies. Correspondingly, if interventions are carried out separately, reviewers can figure out the effectiveness of specified interventions, and so can decision supporters predict the possible effectiveness of their designated interventions. Although it may be tougher for sustainable travel intervention studies to separate different types of interventions than it is in the field of medicine, the hard work is worthy to be conducted so as to enhance the performance of evidence-based methodological framework concerning sustainable travel behavior interventions.

With these research prospects, as a follow suit of evidence-based medicine, a unified framework concerning concepts of evidence-based practice will be constructed, and meanwhile empirical research of sustainable travel behavior interventions will be optimized in terms of recognizability and adoptability. As a result, the subjectivity in decision-making in the field of sustainable travel behavior interventions will be minimized, thus providing aids to decision supporters.

6. Conclusions

Applying evidence-based knowledge graph, we carried out multi-dimensional assessment of sustainable travel behavior evidence, stored the assessment result into knowledge graph to construct evidence database to support decision-making of sustainable travel behavior interventions implementation. Thus, subjectivity in the process of decision-making can be minimized, and a unified decision-making framework can be formed. With the construction and application of the systematic review framework, our study contributes to urban transportation decision-making both in bringing concepts of evidence-based practice into the field of urban transportation and using knowledge graph to organize sustainable travel behavior intervention related empirical evidence. Based on the contributions, we discussed about the usage of the framework in the process of decision-making and raised some research prospects as a reference for other researchers in designing sustainable travel behavior intervention studies.

Our study, as pioneering research in evidence-based decision-making in the field of urban transportation, inevitably exists some shortcomings. Firstly, in terms of method of urban transportation evidence assessment, we mainly draw on relevant methods in the field of evidence-based medicine without considering the uniqueness of urban transportation

evidence, while as few studies mentioned evaluation of evidence in the field of urban transportation, it is very hard to establish an objective framework. These shortcomings in turn result to the inaccuracy in evidence assessment. Secondly, classification of intervention types is also somewhat subjectivity and difficult to achieve an unambiguous classification. Besides, regarding the organization of the evidence knowledge graph, there still exists some room for optimization, which needs to be optimized in conjunction with the practical application of the knowledge graph. Further research should be considered in the future so as to optimize the application of concepts of evidence-based practice in the field of urban transportation, thus realizing objectivity and precision of evidence-based decision-making process.

Conflict of interest

The authors do not have any conflict of interest with other entities or researchers.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtte.2023.10.001.

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Jian Li received his PhD degree in Rutgers University, and is currently an associate professor in College of Transportation Engineering, Tongji University. His research focuses on promoting efficient and sustainable urban mobility with emerging data sources and behavior experiments. In this vein, He is interested in both enhancing current state-of-practice planning tools/platforms and promoting active travel behavior. He published over 50 refereed papers, and has been the principal investigator of 20 projects funded by National Science Foundation of China, Ministry of Science and Technology of China, Federal Ministry for Economic Affairs and Climate Action of Germany, and local governments and consulting companies.