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DISSERTATION

FORMATION OF MANAGEMENT SYSTEM OF UNIVERSITY'S EDUCATIONAL AND SCIENTIFIC ASSETS IN THE CONTEXT OF TRANSITION TO THE MODEL OF CIRCULAR ECONOMY IN CHINA

Speciality 073 - Management

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The dissertation contains the results of own research. The use of ideas, results and texts of other authors have references to the relevant source

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ANNOTATION

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Circular economy (CE) is considered in the scientific community as a remedy for achieving sustainable development goals. The use of renewable energy and the elimination of waste through the perfect design of materials, products, and systems, and within this launch of business models are becoming priority areas for the development of the Chinese economy. The triple function of education, scientific research, and social services of higher education institutions indicates that universities are a driving force in the development of knowledge, values, technology, and the formation of behaviors and lifestyles necessary for the transition to a circular model. Insufficient coverage of issues related to the definition of the theoretical and methodological foundations for managing the university's educational and scientific assets in accordance with the basic principles of the circular model of the Chinese economy determines the relevance and timeliness of the dissertation research.

Based on a systematic literature review, the role and significance of higher education institutions in the development of the CE model in China are analyzed. It is determined that the increase of university research and educational assets in the context of CE is closely related to such factors as institutional design, technological progress, and dissemination of pilot experience. It is found that the transition to a new model of the economy will be longer compared to developed countries due to the lack of public awareness, as well as the inconsistency of modern technologies with the norms and CE principles.

The study identifies key drivers for an accelerated transition to the CE model in China, including (i) appropriate policies and support for the business model

developed by the government, (ii) technological support, (iii) public participation, awareness and knowledge of the circular model, and (iv) economic benefits. The main barriers to the transition to the new model are also identified, including cultural, market, regulatory, and technological barriers. Based on a thorough analysis of these factors, it is proved that universities have the potential to have a significant impact on strengthening the drivers and removing the barriers to the formation of a new model through educational and scientific research activities, which states the significant role of universities in the CE implementation.

The study finds that building up the university's research and educational potential in accordance with the needs of the CE, including green campus initiatives, should be reflected in the university's strategic development plan. It is proved that universities have a significant impact on accelerating the transition to a new model.

Based on the basic principles of CE, the study summarizes the contribution of universities to the implementation of the new model. It is found that previous research in this area of knowledge is fragmented and mainly focuses on CE-related specialties, teaching approaches and tools, as well as CE practices on campus. Based on this, the study substantiates the expediency of forming a system for managing the university's educational and scientific assets, which should be based on the integration of various activities and the involvement of all participants in the research and educational process to enhance the effect of the transition to a new model.

The evolution of management, mechanisms of functioning, and evaluation of sustainable universities are analyzed. It is concluded that the practice of sustainable management in universities has evolved from the "Environmental Management System" to the "Sustainability Management System". In the context of managing university assets related to CE, it is proposed to apply a two-pronged hybrid model that mixed a top-down approach and a participatory approach to guarantee the realization of sustainable development goals.

The study assesses the scientific potential of Chinese universities to implement CE based on the analysis of relevant data in Chinese universities. The analysis of curricula, enrollment plans, and the employment situation in CE-related specialties in Chinese universities shows that universities have significant potential to accelerate the transition to a new model, which involves the introduction of relevant specialties, revision of curricula, enhancement of hidden curriculum, enrichment of general education with CE, advanced training of academic staff related to CE specialties, and expansion of the educational environment. A method of spatial econometrics is proposed to analyze the scientific potential of universities in terms of compliance with the circular model, which allows identifying the dependence of regional technology development on universities through Moran's index and provides stakeholders with guidelines for further investment in research at universities.

It has been established that university innovations have a significant impact on the innovation activities of regional enterprises. In addition, university scientific research has a significant potential to promote technological innovation activities of universities and enterprises in the surrounding regions, which are critical links necessary for the CE implementation.

The expediency of introducing the term "CE-related university assets" into scientific circulation is substantiated, which is proposed to be defined as a set of all types of resources and assets that are formed in the course of university development, are owned and controlled by the university and form the scientific and educational potential of the university to implement the principles of the new model. The study proposes a system of attributes of university assets of the circular model, including non-profit status, technological innovation, education, propagation, and efficient use of resources, which allows interpreting the contribution of different types of university assets in the context of the needs of the CE model. In addition, a classification of CE-related university assets has been developed according to several features, in particular, by purpose (scientific research, education, and operation assets), by form (tangible and intangible assets), by the level of formation costs (high-cost and low-cost assets), by the form of impact (direct and indirect assets), which is useful for decision-makers on sustainable campus development and participants in the educational and scientific process to promote alternative consumption models and shape recycling behavior.

The theoretical foundations for the formation of a system for managing university educational and scientific assets for CE are developed. The proposed system integrates various types of activities and involves all participants in the scientific and educational process. The main activities of the university in the context of CE are studied. In particular, the scientific research activities of the university contribute to the production of ideas and the creation of innovations for enterprises interested in implementing the CE principles. Education activities involve the introduction of new disciplines and specialties for CE professionals, as well as the introduction of appropriate general education for all university students. Social practice and volunteer activities, which are derived from educational activities, define students as subjects for spreading the concept of CE among the public.

The study outlines a scientific and methodological approach to assessing the effectiveness of university asset management in terms of meeting the educational and innovative needs of the circular model, based on 29 indicators, which is useful for creating an information feedback channel for public participation in managing activities related to the implementation of circular model strategies. The assessment system includes target, criterion, and index layers, where each indicator is assigned a corresponding weight. The assessment of the compliance of the university's scientific and educational potential with the needs of the CE is based on the points obtained on the established scale.

This dissertation explores the experience of the waste management program at Leiden University in the Netherlands in the context of management functions, namely planning, organizing, leading, and controlling. Leiden University's waste management plan is fully in line with the objectives of the environmental policy, which details the action plan for fulfilling environmental and sustainable development responsibilities. The specific goals, responsible departments, and implementation of the responsibility status in the areas of education and research are summarized. Compared to other universities, Leiden University applies a basic waste reduction approach to achieve its waste management goals, including waste prevention, waste separation, and recycling. The university's annual sustainability report also confirmed the effectiveness of waste management and commitment to this concept. Based on the results of the study, a draft waste management program is developed at the studied university in line with the experience of universities in the Netherlands, which is based on progressive norms and standards of the European Union for the establishment of a circular model that can be implemented in the context of a campus sustainability strategy.

In the course of the study, interviews are conducted on waste management at the Henan Institute of Science and Technology in China. The analysis showed that on average, the amount of waste at the university is relatively low compared to other Chinese universities, but significantly higher than at universities in the Netherlands. It is found that five waste streams are collected at the university, including food waste, mixed waste, recyclable and non-recyclable waste, and laboratory hazardous waste. The main problems with waste management at the university are identified.

This dissertation presents the results of a survey of 1300 respondents from the Henan Institute of Science and Technology. Statistical analysis methods are used to determine the relationship between the variables. It is found that the dominant factors that influence the behavior of college students regarding waste separation are reminders about waste separation, installation of waste separation containers, and awareness raising. At the same time, five factors have been identified that hinder the process of separate collection, namely knowledge deficiency, outdated equipment, time, lack of incentives, and neglect of personal responsibility. It is found that females are more responsible for separate collection compared to males, and freshmen demonstrates more rational behavior in terms of waste separation, while the behavior of senior students is more sensitive to the identified factors.

The expediency of using artificial intelligence technology for waste management, which covers the processes of waste dumping, separated collection, and sorting, is substantiated. An artificial intelligence-based university waste management system is proposed that applies artificial intelligence technologies to all the processes of managing waste streams, which allows to increase in the efficiency of waste management and accelerate the process of intelligent urban waste management, as opposed to the traditional manual model.

***Key words**:* circular economy, sustainable development, university assets, management system, education, publicity, knowledge spillover, scientific innovation

LIST OF APPLICANT'S PUBLICATIONS

Scientific works reflecting the main scientific results of the dissertation:

1. **Qu, D.**, Shevchenko, T., Shams Esfandabadi, Z., & Ranjbari, M. (2023). College students' attitude towards waste separation and recovery on campus. *Sustainability, 15*(2), 1620. https://doi.org/10.3390/su15021620 **(Scopus & Web of Science)** *(the author conducted the conceptualization, software, formal analysis, investigation, data curation, and visualization, and specifically prepared the initial draft.)*

2. **Qu, D.**, Shevchenko, T., Saidani, M., Xia, Y., & Ladyka, Y. (2021). Transition towards a circular economy: the role of university assets in the implementation of new model. *Detritus, 17*(4), 3-14. https://doi.org/10.31025/2611-4135/2021.15141 (**Scopus & Web of Science)** *(the author developed the methodology, formulated the models, and specifically prepared the initial draft.)*

3. **Qu, D.**, Shevchenko, T., Xia, Y., & Yan, X. (2022). Education and instruction for circular economy: A review on drivers and barriers in circular economy implementation in China. *International Journal of Instruction, 15*(3), 1-22. https://doi.org/10.29333/iji.2022.1531a (**Scopus & Web of Science)** *(the author designed the research framework, conducted the literature collation, performed a statistical analysis of the results, visualized the results, and specifically prepared the initial draft.)*

4. **Qu, D.**, & Shevchenko T. (2020). University curriculum education activities towards circular economy implementation. *International Journal of Scientific & Technology Research*, *9*(5), 200-206. http://www.ijstr.org/final-print/may2020/University-Curriculum-Education-Activities-Towards-Circular-Economy-Implementation.pdf (**Scopus)** *(the author conducted the data collection and collation, performed the analysis of the results, and specifically prepared the initial draft.)*

5. Bliumska-Danko, K., Charreire-Petit, S., **Qu, D.**, & Shevchenko, T.

(2022). Mapping organic packaging research: Environmental concern and health safety. *Environmental Economics*, *13*(1), 155-170. https://doi.org/10.21511/ee.13(1).2022.13 (**Scopus)** *(the author conducted the literature collation and analysis and participated in the initial draft preparation)*

6. Xia, Y., **Qu, D.**, Stoyanets, N., & Zhao, H. (2022). Policy evolution of personnel management in Chinese educational institutions: A comprehensive policy circle analysis. *Problems and Perspectives in Management*, *20*(4), 544-559. https://doi.org/10.21511/ppm.20(4).2022.41 (**Scopus)** *(the author conducted the conceptualization, investigation, visualization and participated in the draft editing)*

7. **Qu, D.**, & Shevchenko, T. (2019). University as a driving force for circular economy implementation in China. *Bulletin of Sumy National Agrarian University*, *1*(79), 14-20. https://doi.org/10.32845/bsnau.2019.1.3 *(the author conducted the data collection and collation, performed a formal analysis of the results, and specifically prepared the initial draft.)*

8. Shevchenko, T., & **Qu, D.** (2019). University's pro-circular activity in transition to circular economy model in China. *Sustainable Development*, 1, 46-51. *(the author conducted literature collation, designed the research framework, and specifically prepared the initial draft.)*

9. **Qu, D.**, & Shevchenko, T. (2022). Advancing waste management program at university in China: enlightenment from the Netherlands. *Bulletin of Sumy National Agrarian University*, *3* (89), 54-65. https://doi.org/10.32845/bsnau.2021.3.8 *(the author conducted a survey of respondents, performed a formal analysis of the results, and specifically prepared the initial draft.)*

10. **Qu, D.**, & Shevchenko, T. (2019). Educational potential of Chinese universities for the implementation of circular economy model. [Monograph]. *New Stages of Development of Modern Science, Izdevnieciba "Baltija Publishing"*, 434-450. https://doi.org/10.30525/978-9934-588-15-0-44 *(the author formulated the research goals and aims, conducted the data collation, and specifically prepared the initial draft.)*

Scientific works certifying the approval of the dissertation materials:

11. **Qu, D.** (2021). Application of artificial intelligence in waste separation management at university. Proceedings of the International Conference on Intelligent Vision and Computing (ICIVC 2021), Springer Book Series, Oman, 15, 330-343. https://doi.org/10.1007/978-3-030-97196-0_27 (**Scopus**)

12. Han, Y., Shevchenko, T., & **Qu, D.** (2022). Smart e-waste management in China: a review. Proceedings of 2nd Congress on Intelligent Systems (CIS2021), Springer Book Series, Singapore, 111. https://doi.org/10.1007/978-981-16-9113-3_38 (**Scopus**) *(the author conducted the literature collation and participated in the initial draft preparation and proof-reading.)*

13. Shevchenko T., & **Qu, D.** (2019). Management strategy for bike-sharing system operation at college campus in compliance with circular economy principles. Proceedings of Conference "Digital and Innovative Economy: Processes, Strategies, Technologies", Poland, 175-177. *(the author conducted the literature collation, designed the methodology, and specifically prepared the initial draft.)*

14. Shevchenko, T., & **Qu, D.** (2019). Formation of universities' pro-circular assets in China to meet the needs of circular economy model. Proceedings of Conference "Modern Problems of the Enterprise management: Theory and Practice", Ukraine, 1-3. *(the author conducted the collation of data and relevant literature and specifically prepared the initial draft.)*

15. **Qu, D.**, & Shevchenko, T. (2019). Development of education for the circular economy in China. Proceedings of Conference "Answers on Nowadays Economic and Environmental Challenges in a Vision of Scientists", Ukraine, 124-127. *(the author designed the research framework, conducted the development of the methodology, and specifically prepared the initial draft.)*

16. **Qu, D.** (2021). Management model of sustainable university: Top-down directives or bottom-up participatory? Proceedings of Conference "Сучасний Менеджмент: Тенденції, Проблеми Та Перспективи Розвитку", Ukraine, 10-13.

17. **Qu, D.**, Shevchenko, T., & Yan, X. (2021). Circular economy models implemented in China. Proceedings of Conference “Answers on Nowadays Economic and Environmental Challenges in a Vision of Scientists”, Ukraine, 62-64. *(the author conducted the literature collation, created the research framework, and specifically prepared the initial draft.)*

18. **Qu, D.** (2019). Technology to optimize the university asset management system. Proceedings of Conference “Management of the XXI Century: Globalization Challenges”, Ukraine, 25-26.

АНОТАЦІЯ

Цюй Дунсюй. Формування системи управління освітніми та науковими активами університету в умовах переходу до моделі циркулярної економіки Китаю. – Кваліфікаційна наукова праця на правах рукопису.

Дисертація на здобуття наукового ступеня доктора філософії за спеціальністю 073 – Менеджмент. – Сумський національний аграрний університет, Суми, 2023.

Циркулярна економіка (ЦЕ) розглядається у науковому колі як модель для досягнення цілей сталого розвитку. Використання відновлюваної енергії та усунення відходів шляхом досконалого дизайну матеріалів, виробів, систем та в рамках цього запуску бізнес-моделей – стають пріоритетними напрямами розвитку китайської економіки. Потрійна функція освіти, наукових досліджень та соціальних послуг вищих навчальних закладів свідчить про те, що університети є рушійною силою у становленні знань, цінностей, створенні технологій, формуванні поведінки та стилю життя, необхідних для переходу до циркулярної моделі. Недостатнє висвітлення питань стосовно визначення теоретико-методологічних засад управління освітніми та науковими активами університету відповідно до базових принципів циркулярної моделі економіки КНР обумовлюють актуальність та своєчасність дисертаційного дослідження.

На основі систематичного огляду літератури було проаналізовано роль та значення закладів вищої освіти для становлення моделі ЦЕ в Китаї. Визначено, що нарощування науково-освітніх активів університету в контексті ЦЕ Китаю тісно пов’язане з такими факторами як інституційний розвиток, технологічний прогрес та поширення пілотного досвіду. Було встановлено, що перехід до нової моделі економіки буде довшим у порівнянні з розвинутими країнами через недостатню обізнаність населення, а також невідповідність сучасних технологій нормам та принципам ЦЕ.

У результаті дослідження встановлено ключові драйвери пришвидшеного переходу на модель ЦЕ в Китаї, до яких слід віднести (i) відповідну політику та підтримку розвитку бізнес-моделей з боку уряду, (ii) технологічну підтримку, (iii) участь громадськості, обізнаність та знання про циркулярну модель та (iv) економічні вигоди. Також було виявлено основні бар'єри переходу на нову модель, зокрема культурні, ринкові, регуляторні та технологічні. За результатом ґрунтовного аналізу зазначених чинників, було доведено, що університети мають потенціал значного впливу на посилення драйверів та усунення перешкод становлення нової моделі через освітню та науково-дослідницьку діяльність, що констатує значну роль університетів у впровадженні ЦЕ.

У процесі дослідження встановлено, що нарощування науково-освітнього потенціалу університету відповідно до потреб ЦЕ, включаючи ініціативи зелених кампусів, має відображатися у стратегічному плані розвитку університету. Доведено, що університети значно впливають на прискорення переходу на нову модель.

На основі базових принципів ЦЕ в роботі встановлено та узагальнено внесок університетів у впровадження нової моделі. Виявлено, що відповідні попередні дослідження у даній галузі знань є фрагментарними і, в основному, зосереджені на спеціальностях, пов'язаних з ЦЕ, підходах до навчання та інструментах, а також практиці ЦЕ в кампусі. Виходячи з цього, в роботі обґрунтовано доцільність формування системи управління освітніми і науковими активами університету, яка має ґрунтуватися на інтеграції різних видів діяльності та залученні усіх учасників науково-освітнього процесу для посилення ефекту переходу на нову модель.

Проведено аналіз еволюції менеджменту, механізмів функціонування та оцінки стійких університетів. Зроблено висновок, що практика сталого менеджменту в університетах зазнала розвитку від «Environmental Management System» до «Sustainability Management System». В контексті управління університетськими активами пов'язаними з ЦЕ, запропоновано застосовувати двосторонню гібридну модель з підходом «зверху вниз», щоб гарантувати реалізацію цілей старого розвитку.

Здійснено оцінку наукового потенціалу китайських університетів щодо впровадження ЦЕ на основі аналізу відповідних даних в університетах Китаю. Аналіз навчальних планів, планів прийому та ситуації з працевлаштуванням за спеціальностями пов'язаними з ЦЕ у китайських університетах, свідчить що університети мають значний потенціал щодо прискорення переходу до нової моделі, що передбачає введення відповідних спеціальностей, перегляд навчальних планів, збагачення загальної освіти ЦЕ, підвищення кваліфікації науково-педагогічних працівників, пов'язаних з спеціальностями ЦЕ та розширення освітнього середовища. Запропоновано метод просторової економетрики для аналізу наукового потенціалу університетів щодо відповідності циркулярній моделі, який дозволяє виявити залежність регіонального розвитку технологій від університетів через індекс Морана та надає зацікавленим сторонам орієнтири для подальшого інвестування в наукові дослідження в університетах.

Встановлено, що університетські інновації мають значний вплив на інноваційну діяльність підприємств регіону. Крім цього, університетські наукові дослідження мають значний потенціал щодо сприяння технологічній інноваційній діяльності університетів і підприємств у прилеглих регіонах, які є критично важливими ланками, необхідними для впровадження ЦЕ.

Обґрунтовано доцільність введення у науковий обіг терміну «науково-освітні активи циркулярної економіки», який запропоновано визначати як сукупність усіх видів ресурсів та активів, що формуються в ході розвитку університету, перебувають у його власності і контролем та утворюють науково-освітній потенціал університету для реалізації принципів нової моделі. Запропоновано систему атрибутів університетських активів циркулярної моделі, серед яких неприбутковість, технологічні інновації, освіта, популяризація та ефективне використання ресурсів, що дозволяють інтерпретувати внесок різних типів університетських активів у контексті потреб циркулярної моделі економіки. Крім того, розроблено класифікацію університетських активів циркулярної економіки за рядом ознак, зокрема за призначенням (наукові, освітні та операційні активи), за формою (матеріальні і нематеріальні активи), за рівнем витрат на формування (активи з високим і низьким рівнем витрат), за формою впливу (прямі і непрямі активи), яка є корисною для осіб, що приймають рішення щодо сталого розвитку кампусу та учасників освітньо-наукового процесу для популяризації альтернативних моделей споживання та формування поведінки ресайклінгу.

Розроблено теоретичні засади формування системи управління освітніми і науковими активами університету для ЦЕ. Запропонована система інтегрує різні види діяльності та залучає усіх учасників науково-освітнього процесу. Досліджено основні види діяльності університету в контексті ЦЕ. Зокрема науково-дослідницька діяльність університету сприяє продукуванню ідей та створенню інновацій для підприємств, що зацікавлені у впровадженні принципів ЦЕ. Освітня діяльність передбачає введення нових дисциплін та спеціальностей для професіоналів ЦЕ, а також впровадження відповідної загальної освіти для всіх студентів університету. Соціальна практика та волонтерська діяльність, що є похідною від освітньої діяльності, визначає студентів як суб’єктів для поширення концепції ЦЕ серед громадськості.

У роботі викладено науково-методичний підхід щодо оцінки ефективності управління університетськими активами з точки зору задоволення освітніх та інноваційних потреб циркулярної моделі, в основу якого покладено 29 індикаторів, що є корисним для створення інформаційного каналу зворотного зв'язку для участі громадськості в управлінні діяльностями, пов'язаними з введенням в дію стратегій циркулярної моделі. Система оцінок включає цільовий, критеріальний та індексний рівні, де кожному показнику присвоєно відповідну вагу. Оцінка відповідності науково-освітнього потенціалу університету потребам ЦЕ відбувається на основі отриманих балів за встановленою шкалою.

В дисертації досліджено досвід програми управління відходами в Лейденському університеті в Нідерландах в контексті функцій управління, а саме планування, організацію, координацію та контроль. План управління відходами Лейденського університету повністю відповідає цілям екологічної політики, де детально прописано план дій щодо виконання обов'язків у сфері охорони навколишнього середовища та сталого розвитку. Було узагальнено цілі, відповідальні відділи та впровадження статусу відповідальності у сферах освіти та досліджень. У порівнянні з іншими університетами, Лейденський університет застосовує базовий підхід до зменшення відходів для досягнення цілей управління відходами, включаючи запобігання утворенню відходів, їх розділення і переробку. Річний звіт про сталий розвиток університету також став підтвердженням ефективності управління відходами та прихильність до даної концепції. За результатами дослідження розроблено проєкт програми управління відходами у досліджуваному університеті, виходячи з досвіду університетів Нідерландів, в основу якого покладено прогресивні норми та стандарти Європейського Союзу щодо становлення циркулярної моделі, який може бути впроваджений в контексті стратегії сталого розвитку кампусу.

В процесі дослідження було проведено інтерв'ю щодо поводження з відходами в Хенанському інституті науки і технологій у Китаї. Аналіз показав, що в середньому обсяг відходів в університеті відносно низький у порівнянні з іншими китайськими університетами, але значно більший, ніж в університетах Нідерландів. Виявлено, що існує п'ять потоків відходів, які збираються в університеті, включаючи харчові відходи, відходи змішані, відходи, що підлягають та не підлягають переробці, і лабораторні небезпечні відходи. Встановлено основні проблеми щодо поводження з відходами в університеті.

У дисертаційній роботі викладено результати опитування 1300 респондентів Хенанського інституту науки і технологій. Методи статистичного аналізу були використані для визначення зв'язку між змінними. Виявлено, що домінуючими факторами, які впливають на поведінку студентів коледжу щодо розділення відходів є нагадування про розділення відходів, встановлення контейнерів для розділення відходів, проведення інформаційно-роз’яснювальної роботи. Водночас виявлено п’ять факторів, які стримують процес роздільного збирання, а саме брак знань, застаріле обладнання, кількість часу, відсутність стимулювання та нехтування особистою відповідальністю. Встановлено, що жінки є більш відповідальними щодо роздільного збирання у порівнянні з чоловіками, а першокурсники продемонстрували більш раціональну поведінку щодо розділення сміття, тоді як поведінка студентів старших курсів була більш чутливою до встановлених факторів.

Обґрунтовано доцільність використання технології штучного інтелекту щодо поводження з відходами, що охоплює процеси накопичення відходів, роздільне збирання та сортування. Запропоновано систему управління відходами в університеті на основі штучного інтелекту, яка застосовує технології штучного інтелекту до процесу управління потоками відходів, включаючи видалення відходів, роздільний збір та сортування, що дозволяє підвищити ефективність управління відходами та прискорити процес інтелектуального управління міськими відходами, на відміну від традиційного ручного режиму.

Ключові слова: циркулярна економіка, сталий розвиток, університетські активи, система управління, освіта, публічність, поширення знань, наукові інновації.

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ONTENT

LIST OF SYMBOLS

ACU	-	Association of Commonwealth Universities
AI	-	Artificial Intelligence
AISHE	-	Auditing Instrument for Sustainability in Higher Education
CE	-	Circular Economy
CSAF	-	Campus Sustainability Assessment Framework
CSARP	-	Campus Sustainability Assessment Review Project
CSRC	-	College Sustainability Report Card
ECE	-	Education for Circular Economy
ESD	-	Education for Sustainable Development
GCCAP	-	Green Campus Construction Action Program
GCES	-	Green Campus Evaluation Standards (GB/T51356-2019)
LEED	-	Leadership in Energy & Environmental Design
MOHURD	-	Ministry of Housing and Urban-rural Development
NWF-SCE	-	National Wildlife Federation's State of the Campus Environment
PA	-	Participatory Approach
PMD	-	Plastic Packaging, Metal and Drinking Cartons
PSIR	-	Penn State Indicators Report
RRSE	-	Resource Recycling Science and Engineering
SD	-	Sustainable Development
SDGs	-	Sustainable Development Goals
SMS	-	Sustainable Management System
TDA	-	Top-down Approach
UCEE	-	University circular economy education
UCEE	-	University Circular Economy Education
UIGWUR	-	UI GreenMetric World University Rankings
ULSF-SAQ	-	University Leaders for a Sustainable Future's Sustainability Assessment Questionnaire
UNCED	-	United Nations Conference on Environment and development
UNCHE	-	United Nations Conference on the Human Environment
UNESCO	-	United Nations Educational, Scientific, and Cultural Organization
UNGA	-	United Nations General Assembly
USGBC	-	United States Green Building Council

INTRODUCTION

Relevance of the topic. Today's planet is experiencing severe environmental damage, climate warming, and resource scarcity. The reason for this is still due to the irreversible negative impact of the traditional linear economy on resources and the environment. As a new alternative, the circular economy (CE) proposed by British scholars in their spaceship theory emphasizes the need to recycle material resources in a closed loop to avoid the eventual collapse of human society due to the depletion of the earth's finite resources and the pollution of waste. Generally, the emergence of the CE has raised hopes for the rebuilding of a green planet due to the recycling of resources and ecological restoration that it can bring.

The CE model is seen as a remedy to achieve the goal of sustainable development (SD) of the planet and can bring back all the off-track behaviors. Most countries and industries around the world have started theoretical research and practical exploration of CE, hoping to follow the principles of CE in the pursuit of social progress and economic development to recycle limited resources as much as possible and reduce the negative impact on the earth's ecological environment. However, in practice, only a few professionals can understand and practice the CE to maintain the connection between the natural world and human beings. In other words, there are multiple obstacles and challenges to implement the CE, which are driving the CE off the right track. For example, the loss of interest in the transition of traditional production methods of enterprises, the lack of top-down initiative in each country to implement the CE, change of traditional consumption habits and behavior patterns of residents, etc. Therefore, there is a need for a mature and sound motivation mechanism to remove these obstacles, and unify the thoughts and actions of various stakeholders' interests in one place to gather strength to accelerate the transition toward a CE model.

In general, the CE is driven by government, business, and society. However, to remove the barriers at the root, it is necessary to use education to change thinking and values. Universities need to be involved as a new force to make their contribution with their rich teaching and research resources and social influence. Ideally, universities will produce future scientists, engineers, and business people who rely on scientific innovation, technological design, and institutional design of economic activities to maintain ecological balance and avoid damage to the natural environment, while enhancing human health and well-being. In the future, the concept of waste or pollutants will be eliminated, because each waste will provide raw materials for other products, or nutrients for other species, or will be returned to the ecological cycle of nature. Therefore, realizing such an ambitious vision requires higher education institutions to assume a significant responsibility to increase the dissemination of knowledge and skills related to SD and CE, thus leading to a paradigm shift in values instead of utilitarian education.

The contribution of higher education to the CE can be traced back to education for SD and the construction of green/sustainable universities in higher education. Since 1972, when the Stockholm Declaration first raised the issue of sustainability in higher education, many universities have become aware of their responsibilities. They have made public commitments to engage in education for sustainable action. The assumption by universities of their responsibility for SD means that they have begun to participate in determining the future of humans and other species living on an increasingly resource-poor planet through their triple role of education/research and social service. CE is a more operational and concrete concept than SD.

However, not many studies have been conducted on the contribution of universities to CE. A bibliometric study shows that the leading scientists that focus on this field mainly include Kilkis S., Kirchherr J., Whalen K.A., Mendoza J.M.E., Kopnina H., Mendoza J.M.F., Salguero-Puerta L., Nunes B.T., Rokicki T., De Medici S., Ramakrishna S., Rodriguez-Chueca J., Stephan A., Wandl A., Pelau C., Brenes-Peralta L., Bugallo-Rodriguez A., Tuerkeli S., Lanz M, Nibbi L., Maruyama U., Carbonell-Alcocer A, and Shevchenko T. Although education for SD (ESD) and education for CE (ECE) have been in the spotlight for many years, there is still enough room to enhance the performance of the CE through higher education/research and campus operations management. Especially in some developing countries, such as China, the potential of universities to contribute to the CE needs to be further explored and developed. Specifically, it is necessary to develop an adequate theoretical framework for the CE and an operational asset management model towards the CE in Chinese universities. Under this management model, universities can provide scientific and technological support for the development of CE and involve more people in CE initiatives through campus CE operation practices and education. All this determined the choice of the topic, purpose and objectives of the study.

Connection of work with scientific programs, plans, topics.

The subject of this study is consistent with the basic principles of "The 2030 Agenda for Sustainable Development" (Resolution 70/1 of UN General Assembly), the "European Green Deal" (Announcement of the European Commission in 2019), the "Sustainable Development Strategy of Ukraine until 2030" (draft No. 9015 of 07.08.2018), and "China's National Plan on the Implementation of the 2030 Agenda for Sustainable Development" (Announcement of the Chinese government in 2019).

The dissertation was carried out following the topic of scientific research of the Erasmus+ Programme of the European Union within the project "Towards circular economy thinking & ideation in Ukraine according to the EU action plan" (grant number 620966-EPP-1-2020), in which the author investigated the foreign experience of management of CE-related assets in higher educational institutions.

The purpose and objectives of the study. The purpose of the dissertation research is to develop theoretical and scientific and methodological foundations for forming the system of management of educational and scientific assets of universities in the context of the transition to the model of the CE of China.

Achievement of the purpose necessitates the following main tasks:

- To generalize progressive modern management approaches and practical experience of sustainable universities to provide reference to the establishment of a more practical management system based on CE-related assets in universities;

- To analyze the current state and trends of the development of Chinese universities in the direction of building up both educational and scientific potential;

- To develop a scientific and methodical approach to form a management system of CE-related assets of universities for the development of a CE in China;

- To develop an evaluation index system to assess the management performance of CE-related university assets by calculating the circularity degree;

- To conduct a case study on the status of waste management at Chinese universities to determine the ideal shape of an effective university waste management program;

- To survey college students' waste separation attitudes and behaviors at Chinese universities to explore the dominant factors that influence the effectiveness of waste separation and recovery.

The object of the study is the system of management of educational and scientific assets of the university.

The subject of the study is the methods and tools for managing the scientific and educational assets of universities following the requirements of the CE model.

Research methods. The methodological basis of the dissertation work is the fundamental provisions of economic theory and management theory, which became the basis for research on the development and management of CE-related university assets. In accordance with the defined tasks, a wide list of research methods were adopted in the study, such as: trend and bibliometric analyses - to identify the main drivers and barriers in CE implementation; system analysis and generalization methods - to systematize the factors of influence on the efficiency of the functioning of the system and substantiate the asset management tools in the study of existing models of a modern university; structural-logical analysis - to develop the preconditions and principles of formation of the system of management of educational and scientific assets of universities in accordance with the requirements of the circular model; causal and consequential connections - to clarify the essence of the notion of "CE-related university assets"; statistical analysis and comparison - to identify the current state and trends of the development of Chinese universities in the direction of building up both educational and scientific potential; surveys and interviews - to test scientific hypotheses are scheduled to be held at H university in Henan provinces of China.

The information base of the study was the legislative and regulatory acts of the People’s Republic of China, official materials of the Committee of Statistics of the People’s Republic of China (the Ministry of Education, the National Bureau of Statistics, the Ministry of Housing and Urban-rural Development, the National Development and Reform Commission, the State Council, etc.) and the provinces, scientific articles of Ukrainian, Chinese, and foreign authors, reports, analytical documents, Internet resources, and author’s calculations.

The scientific novelty of the obtained results is the development of the extant theoretical provisions for the introduction of CE-related university assets for the formation of a comprehensive management system of CE-related assets of Chinese universities in accordance with the requirements of the development of China’s CE models. The scientific essence could be concluded as follows:

First obtained:

- A scientific and methodological approach to the formation of a system for managing the university's educational and scientific assets is proposed as an integral element of the CE model, based on the integration of various activities and the involvement of all participants in the research and educational process to enhance the effect of the transition to a new model.

Improved:

- A classification of CE-related university assets has been developed according to several features, in particular, by purpose (scientific research, education, and operation assets), by morphology (tangible and intangible assets), by the level of formation costs (high-cost and low-cost assets), by the form of impact (direct and indirect assets), which are beneficial for decision-makers on sustainable campus development and participants in the educational and scientific process to popularize alternative consumption models and form recycling behavior.

- A scientific and methodological approach to assessing the management performance of CE-related university assets based on 29 indicators is proposed in terms of meeting the educational and innovative needs of the circular model, which is useful for creating an information feedback channel for public participation in the management of activities related to the implementation of circular model strategies.

- A method of spatial econometrics is proposed to analyze the scientific potential of universities in terms of compliance with the circular model, which allows to identify the dependence of regional technology development on universities through Moran's index and provides stakeholders with guidelines for further investment in scientific research at universities.

- A draft waste management program at the Henan Institute of Science and Technology is developed inspired by the experience of universities in the Netherlands, which is based on progressive norms and standards of the European Union for the establishment of a circular model that can be implemented in the context of the campus sustainable development strategy.

Further developed:

- An artificial intelligence-based waste management system at universities is proposed, which applies artificial intelligence technologies to the process of managing waste streams, including waste dumping, separated collection, and sorting, which allows to increase the efficiency of waste management and accelerate the process of intelligent urban waste management, as opposed to the traditional manual mode.

- The expediency of introducing the term "CE-related university assets" into scientific circulation is substantiated, which is proposed to be defined as a set of all types of resources and assets that are formed in the course of university development, are owned and controlled by the university and form the scientific and educational potential of the university to implement the principles of the new model.

- A system of attributes of university assets of the circular model is proposed, including non-profit, technology innovation, education, propagation, and efficient use of resources, which allows interpreting the contribution of different types of university assets in the context of the needs of the CE model.

The scientific and practical significance of the dissertation is that the main provisions of the thesis are brought to the level of methodological developments and practical recommendations that were used in the work of the School of Education Science of Henan Institute of Science and Technology in the development of strategies and programs for the "Fixed assets management plan", see Appendix B. The research materials of the thesis are used in the educational process of the disciplines "Educational Dissemination" and "Pedagogy" for undergraduate students majoring in 040104 Educational Technology at Henan Institute of Science and Technology, see Appendix C. The proposal of the waste management program for H university in this study has been considered by the decision-makers in improving the waste management at H University and even could be applied to the urban waste management of the city where it is located after mature development.

Applicant's personal contribution. The dissertation is completed scientific research. The scientific provisions, conclusions, and suggestions submitted for defense are obtained by the author independently and reflected in published works.

Approbation of the results of the dissertation. The main results of the dissertation were published at 8 national and international scientific conferences ([11-18] in the list of publications given in the annotation), the most important of which was the International Scientific Conference "Digital and Innovative Economy: Processes, Strategies, Technologies", (15.01.2019, Poland), International Scientific Conference "Answers on Nowadays Economic and Environmental Challenges in a Vision of Scientists", (25-26.06.2019, Odessa, Ukraine), Ⅶ International Scientific-Practical Conference "Modern Management: Trends, Problems and Prospects for Development" (14.04.2021, Dnipro, Ukraine), International Scientific Internet-Conference "Economic and Environmental Problems of Contemporaneity in Researches of Scientists", (29.06.2021, Odessa, Ukraine), 2nd Congress on Intelligent Systems (CIS), (04-05.09.2021, Bengaluru, India), and the International Conference on Intelligent Vision and Computing (ICIVC), (03-04, 10.2021, Oman).

Publication of obtained results. The main provisions of the dissertation are published in 18 scientific publications, including subsections in 1 collective monograph; 2 articles in scientific professional publications of Ukraine, which are included in international scient metric databases, 6 articles in a foreign publication indexed by the Scopus or Web of Science database; 1 article in other publications in a foreign country; 8 publications in the proceedings of scientific conferences.

Scope and structure of the dissertation. The dissertation consists of an introduction, three sections, conclusions, a list of references, and appendices. The total volume of the dissertation is 233 pages, in particular: 186 pages of the main text, 40 tables, 37 figures, and 3 appendix, a list of references that includes 242 items on 18 pages.

SECTION 1. THEORETICAL BACKGROUND OF HIGHER EDUCATION INSTITUTIONS IN PROMOTING CE IMPLEMENTATION

1.1 Essence and value of universities to contribute to CE transition

The shortage of resources and environmental pollution has always been the main problems faced in global economic development. Compared with the increasing demand of human beings, the issue of insufficient supply of resources is becoming more and more serious. Human beings are facing the severe challenge of shortage or even depletion of essential resources such as water, land, forest, and minerals. At the same time, due to the excessive and rapid demand for resources from nature and the discharge of waste, the earth's environment in which human beings' lives has degraded rapidly, and global environmental problems have arisen, mainly including global warming, ozone hole, desertification, and environmental pollution.

The concept of Earth Overshoot Day is often used to assess the relative relationship between the earth's bioburden (or the number of resources that the earth regenerates in a year) and humanity's annual ecological footprint (which can be understood as the amount of resource consumption). That is to say, Earth Overshoot Day marks the date when humanity's demand for ecological resources and services in a given year exceeds what earth can regenerate in that year (Planet's Biocapacity / Humanity's Ecological Footprint x 365 = Earth Overshoot Day). Data from the research organization "Global Footprint Network" (GFN, 2022) shows that in addition to the decline in resource use in 2020 due to the global new crown epidemic, the date of "overload day" has been advancing continuously in the past few decades, see Figure 1.1. In the 1970s, "Overload Day" did not arrive until November and December each year, while Earth Overshoot Day in 2021 fell on July 29. It is predicted that if the world's population lived like before, the country overshoot days in 2022 around the world would also continue the trend of advancing, see Figure 1.2. The rate of human consumption of the earth's resources is constantly hitting a new record high, and the total global resource demand is expected to double by 2050 (Geng et al., 2019).

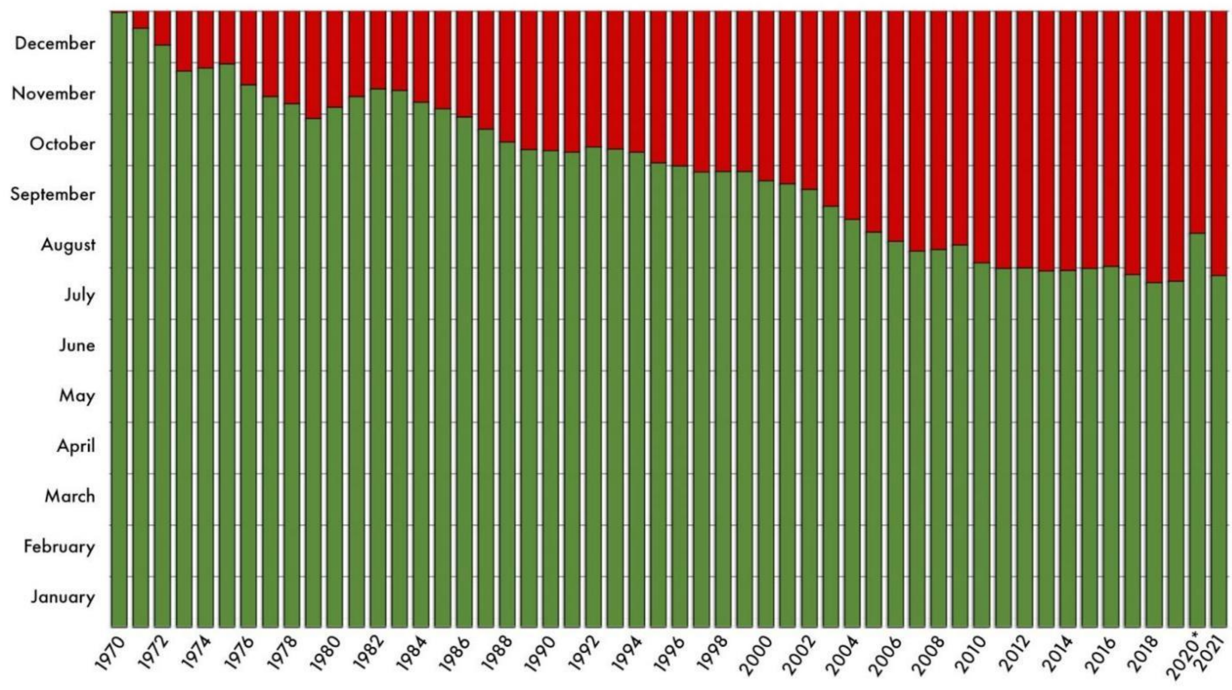

Figure 1.1 - Earth overshoot day from 1970 to 2021

Source: prepared by the author based on National Footprint and Biocapacity Accounts, 2021 Edition (GFN, 2022)

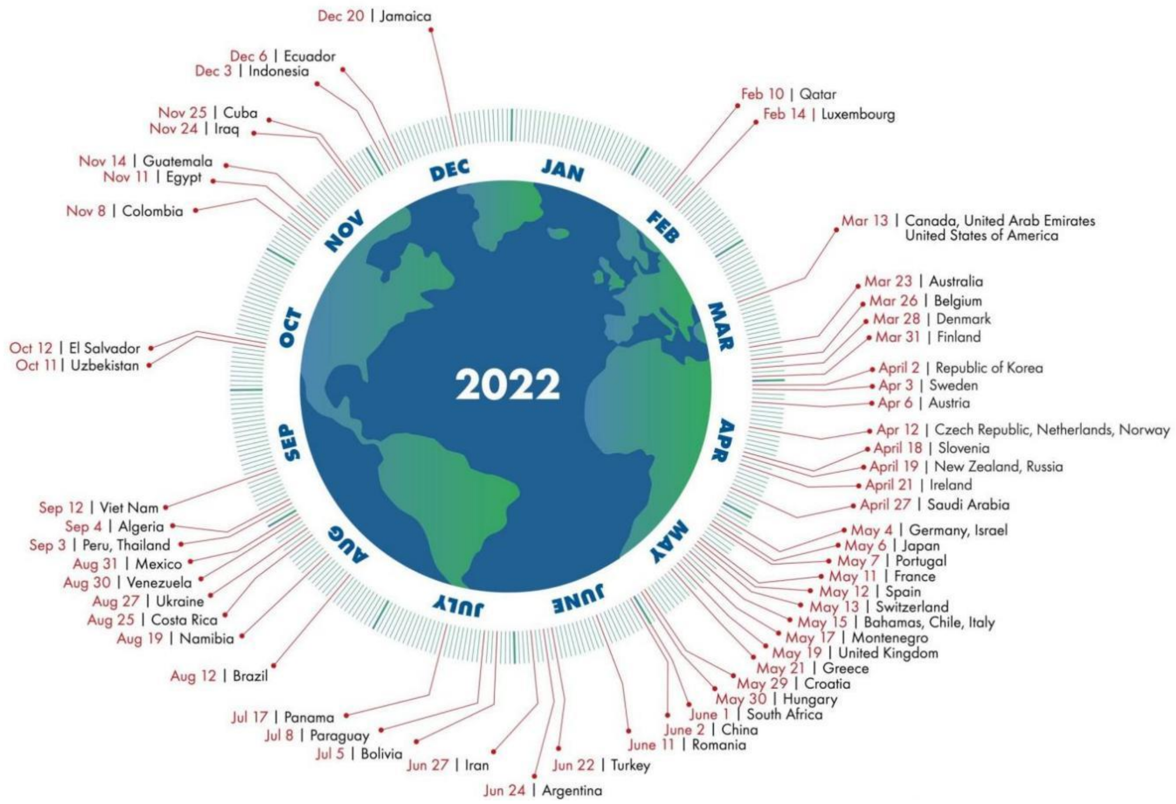

Figure 1.2 - Extrapolation of country overshoot Day in 2022

Source: prepared by the author based on National Footprint and Biocapacity Accounts, 2022 Edition (GFN, 2022)

However, the waste of resources and the consequent environmental pollution coincide with the consumption of resources. Under the current economic development model, there is a waste of resources in the process of product production, consumption, and use. Most of these wastes are not recycled, causing environmental pollution. For example, it takes a ton of metal, silicon, and plastic to produce a few kilograms of laptops that are most used in our daily lives. However, astonishingly, only 6% of the material is recycled, and the vast amount of the remaining material that could have been recycled fails to enter the normal recycling process for various reasons (Geng et al., 2019). In addition, 8 million tons of plastic are dumped as waste every year into Ocean. If these plastics are recycled, products made from recycled plastics can not only reduce the cost of products by about 80% but also avoid plastic pollution of seawater and harm to marine species. The same resource waste problem also occurs in the use of other materials so that the life cycle that could have been extended is ended. Therefore, it is necessary to manage the earth's limited resources sustainably to extend the useful life of the resources as much as possible. The model of SD has been generally recognized by countries around the world as an inevitable choice for economic development, and the CE model is a reliable path for realizing Sustainable Development Goals (SDGs).

Special focus on the origin of the CE model. The idea of CE originated from the "Spaceship Theory" proposed by Boulding (1966), who proposed that human society would eventually collapse as the earth's finite resources were exhausted and the waste was polluted. The only solution is to form a new economic model that can realize the recycling of materials in a closed-loop to replace the traditional single-program development model. The CE concept was first raised in the book "Natural Resources and Environmental Economics" by two British environmental economists, Pearce, and Turner (1990), who pointed out that a traditional open-ended economy could be and should be converted to a CE model with the closed-loop of resource recycling. Since then, academia, international organizations, and governments of various countries have carried out a lot of research, implementation, and practice, constantly enriching and improving the connotation of CE (Lin & Wang, 2019).

However, scholars have been arguing about the exact concept of CE. Some researchers confirmed that CE is a crucial factor and a meaningful way to achieve SD (Yue, 2010; Ghisellini et al., 2016) because the latter concept has been described as too vague to be implemented and is starting to lose momentum (van den Brande et al., 2011). Other researchers argue that CE's link to SD is weak (Kirchherr et al., 2017). Specifically, SD is a scientific development path concerning the three-dimensional harmonious coexistence of economy, society, and ecological environment. Therefore, ESD intends to promote the realization of the 17 SDGs by exerting the function of education at three levels below. The first level is to make the transition to a sustainable economic growth model, such as decent work and economic growth (SDG 8). The other is to foster the harmonious development and progress of society, such as no poverty (SDG 1) and zero hunger (SDG 2). The third level is to preserve and recover the ecological environment, such as climate action (SDG 13) and life under water (SDG 14).

Compared with the grandiose concept of SD, the concept of CE is relatively concrete and realistic, which is viewed as an operationalization of SD (Murray et al., 2017). The CE is most frequently depicted as a combination of reducing, reusing, and recycling activities with the main aim of economic prosperity and environmental quality, whereas it is oftentimes not highlighted that CE necessitates a systemic shift (Kirchherr et al., 2017). To the best of our knowledge, CE is a new economic system that replaces the "take-make-waste" linear model with the "cradle to cradle" concept in the whole life cycle of materials by reducing, alternatively reusing, and recycling the resources and assets in the process of production and consumption (Ghisellini et al., 2016), aiming to decouple economic growth from finite resource consumption and environmental degradation by reducing waste and maximizing resource utilization (EMF, 2021). By combing the existing literature, it can be concluded that the core connotation of CE is mainly reflected in its topology and core ideas.

- CE core idea. The core idea of CE is mainly reflected in the code of conduct and principles for CE implementation. Germany first started the CE implementation and then enacted a law with wide worldwide impact named “CE and Waste Management Law” after a series of CE practices in significant areas (UBA,1994), in which the so-called 3R principles of CE were proposed that includes reduce, reuse and recycle. Reduction aims to reduce resource consumption and waste generation during production, distribution, and consumption. Reuse refers to the use of waste as a product directly or after repair, renovation, and remanufacturing, or the use of all or part of the waste as a component of other products. Recycling refers to the direct utilization of wastes as raw materials or the recycling of waste. Up to now, 3Rs have become the dominant operationalization principle among the CE principle ranging from 3Rs to 10Rs.

There are three cyclic processes that could be extracted from the CE framework (Morseletto, 2020). The first is the service cycle based on the Reduce principle. That is, by investing in a CE-oriented human capital support system, the top-level design and value reconstruction of CE service could be realized to reduce or even avoid the use of unnecessary resources to cut down the occurrence of new waste, for example, the CE training and education, CE design and technological innovation, the Empty Plate Campaign launched in canteens, and the Plastic Limit Campaign initiated among consumers. The second is the material cycle based on the Reuse principle. The material capital could be allocated efficiently to realize the most reasonable utilization of all materials through the transfer or sharing of the ownership or right to use of the resources, such as second-hand idle goods trading platform, idle furniture transfer, shared transportation service, and other shared services in public places like shared bookstores. The third process is waste recycling based on Recycle principle. The valuable materials in the waste could be recycled and remanufactured to give new life to the materials to improve the utilization efficiency, such as the domestic waste sorting system, cartoon waste recovery system, and reclaimed wastewater treatment system. All these cyclic processes mainly focus on the goals of improving the utilization efficiency of resources and assets and reducing waste through the input of human capital and the diversified allocation of physical capital.

The 3R principles constitute the basic idea of CE, but this does not mean that their importance in CE implementation is juxtaposed. CE does not simply realize waste recycling through recycling but emphasizes the priority of reducing resources. The 3Rs are applied comprehensively based on consumption and waste generation. Therefore, the priority order of the 3Rs principles is reduction first and recycling last. Recently, multiple researchers have stressed the importance of considering up to 10R strategies, which were distinguished into three kinds of loops according to the length of the cycle period. The first is short loops in which products remain close to their user and function, including Refuse/Rethink (R0), Reduce (R1), Resell/reuse (R2), and Repair (R3). The medium-long loops refer to the products being upgraded and producers being involved again, such as Refurbish (R4), Remanufacture (R5), and Repurpose (R6). The long loops include Recycle (R7), Recover (R8), and Re-mine (R9), where products lose their original function and need to be converted to other forms to be used (Reike et al., 2018). Compared with the 3Rs, the new principles are more specific and actionable and involve a more comprehensive range of production areas.

- CE topology structure. The evolution process from the traditional linear economy to the increasingly prosperous closed-loop economic model has undergone several development stages, such as pollution, governance, and source governance. The advantages of the CE model can be better demonstrated by analyzing and comparing the system structures of the two economic development modes, as shown in Figure 1.3. The traditional economic model belongs to the linear economy or the open-loop economy, which is an economic model characterized by the linear flow of resources (Bilitewski, 2012). The specific manifestation is the one-way flow of “natural resources-products-waste” in the traditional economy, that is, the process from cradle to grave. The so-called “cradle” refers to the extraction and consumption of natural resources, which are then transformed into products through raw material processing and industrial production, and then enter the process of consumption and use of products. In the linear economic model, the only goal of enterprises is economic interests, and social and environmental efficiency are very low. Therefore, the pollutants and wastes generated in the initial economic activities are directly discharged into the natural environment without treatment, causing severe resource abuse and environmental pollution. Although the pollution control work in many countries has reduced environmental pollution to a certain extent since the 1970s, it still does not change the essence of the linear economy because the one-way flow of resources/products leads to the problem that resources cannot be fully utilized has not changed (Zhang, 2021).

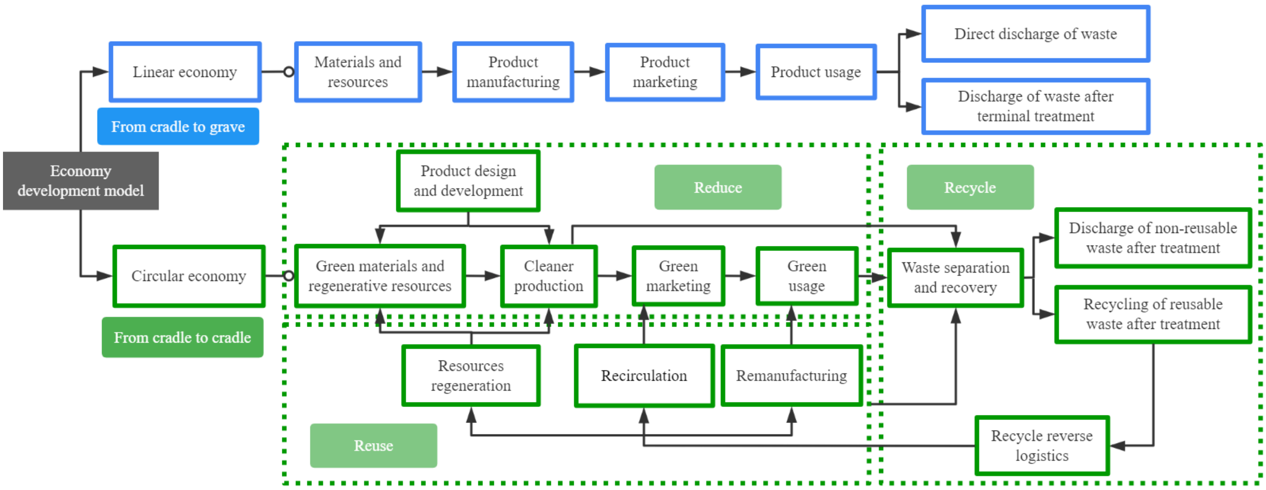

Figure 1.3 - Comparison of structure between linear economic model and CE model

Source: prepared by the author

In contrast to the linear economic model, CE is a closed-loop economy characterized by resource conservation and recycling, embodied in the feedback process of "resource-products and service-renewable resource" in economic activities, that is, the process from cradle to cradle. The ultimate goal of promoting CE is to improve the efficiency of resource utilization and the ecological environment by decoupling environmental pressure from economic growth. As a sustainable economic development model, CE requires enterprises to find an ideal balance among economic benefits, social benefits, and ecological benefits so as to achieve the coordinated development of the three. To achieve this goal, product design, and development, as well as the selection of renewable resources and materials, are necessary before production. The public also needs to play an important role in reduction, including green consumption, green use, and sorting and recycling of waste.

In essence, CE reflects a new model of productivity development, which is bound to have corresponding requirements on the existing science and technology, the basis of productivity, and people's cognitive level of CE (Sun, 2013). On the one hand, the CE model is an economic model with a high and new technology industry as the forerunner. By developing the technology of economic utilization and efficient recycling of natural resources, CE implementation is provided the possibility (Gong, 2010). The emergence of this possibility and whether this possibility can be turned into reality mainly depends on CE professional education. On the other hand, in the way of an economic model developed in a knowledge-based society, the CE model needs the understanding, support, and cooperation of the whole society, that is, the CE implementation needs to carry on the CE general education for all citizens (Yao, 2006). There is consensus that education is a dominant intervening measure in changing the knowledge, values, behaviors, and lifestyles needed to achieve SD (Berryman & Sauvé, 2016). As the engine of knowledge and technology, the role of higher education in carrying out education for CE has been highlighted in recent years. In particular, the positive influence of educational and research assets in universities on CE model has been proved (Qu & Shevchenko, 2019), which is an essential basis for this study.

Exploration of CE models in China: from theory to practice. So far, the CE practice in developed countries is primarily to achieve material closed-loop flow at different levels based on 3R principles (reduce, reuse and recycle) and has formed several classic models in the early process of industrial structure optimization and upgrading, such as American DuPont model that focuses on the internal resource recycling utilization of a single enterprise, Danish Kalundborg

Ecological Industrial Park model that orienting to the ecological network system of symbiotic enterprises, German Dual Recycling System model that connecting production and consumption, and Japanese Recycling Society model for the whole society. However, developing countries still rely on the traditional linear economic model to a certain extent because they are at a relatively low stage of social and economic development, and the transition to a CE model still requires a certain period of effort. Therefore, how to help developing countries realize the transition to a CE model as soon as possible has become a general concern for researchers.

As the largest developing country, China has permanently attached great importance to the realization of CE. To respond to the increasing global environmental pollution and excessive resource consumption, China announced in 2020 that it would increase its independent national contribution and adopt more aggressive policies and measures to achieve carbon neutrality by 2060. China is the world's largest carbon emitter and energy consumer, so China's commitment will have a profound impact on the global energy economy. It can be predicted that China will put more effort into CE implementation in future development. In fact, since the CE legislation was enacted in 2009, all sectors of society, from the state to the local, have been conducting theoretical and practical explorations of CE models suitable for China's national conditions. The main achievements of CE models in China are shown in Table 1.1.

Table 1.1 - China's CE models in theory and practice

Different fields		Main models
Theoretical research	implementation strategy	Model C (Zhu, 2009), "Crossing the Environment Mountain" strategy (Lu and Mao, 2003), "Climbing the Environmental Mountain" strategy (Jin et al., 2010)
	implementation approach	"3+1" model (Sun, 2014), "Object-Subject-Policy" model (Zhu and Huang, 2005), Regional CE models (Xiao, 2007; Liu and Zhang, 2014), "2 +4" model (Wang, 2006), "Three Level Cycle" model (Xie, 2004), "5 + 1" model (Liu, 2005)
Practical exploration		"3+1" model that includes three levels of enterprises, regions, society, and the vein industry ((Pei and Zhao, 2016; Liu and Li, 2018; Chen et al., 2019)

Source: prepared by the author

In theory, the experts and scholars have explored the implementation strategy and implementation approach of CE based on the CE model implemented abroad and in combination with the reality of China’s economic development (Lu & Chen, 2014).

In terms of the implementation strategy, based on the “B Model” originated by Lester R. Brown (2009), Zhu (2009) proposed the “C Model” according to the actual situation in China, which is also known as a 1.5-2 multiples development strategy. In his opinion, the CE model and corresponding evaluation standard for China should be in line with China’s specific national conditions because of China’s international status as the largest developing country in the world, and there is needed a 15–20-year adjustment buffer stage in China to achieve a CE model in which economic growth and resource consumption are relatively decoupled due to the limitations of technical capabilities and management level (Zhu, 2013). Lu and Mao (2003) deduced the relationship between environmental load and GDP, and put forward the strategy of “Crossing the Environment Mountain”. That is to say, the environmental load curve in progress from the traditional linear economic model to the terminal management model and then to the CE model was compared to “Environmental Mountains”, and it is considered that taking a new industrialized road that can pass through the “Environmental Mountains” from the mountainside is a strategic choice for China’s transition to a CE model (Li, 2018). Jin Yong et al. (2010) combined the available literature and brought forward a new model called the “Climbing Strategy” because the “C Model” strategy is more in line with China’s actual situation and the “Crossing the Environment Mountain” strategy is difficult to achieve under current technical conditions. It is considered that climbing the “Environmental Mountain” smoothly is a better way of transitioning to a CE model with the condition of increasing GDP and technology levels (Lu and Chen, 2014).

In terms of implementation approach, the “3+1” model proposed by China’s State Environmental Protection Administration is the main model for China to promote CE implementation, that is, a small cycle at the enterprise level, a medium cycle at the regional level, a large cycle at the social level, and the waste disposal and recycling industry or renewable resource industry (Sun, 2014). Zhu & Huang (2005) put forward the “Object-Subject-Policy” model, in which the object refers to the whole process management of resources, the subject relates to the participation of enterprises, citizens, and the government, as well as the policy, relates to the implementation of regulatory policies, market policies and participatory policies, which is a good supplement and deepening of the “3+1” model. Xiao (2007) argued that the CE implementation model should be based on local conditions, and combined with the various characteristics of different regions in China to design several types of featured regional CE models, such as the industrial ecological park integration model, virtual bionic cycle model, and enterprise internal clean production model. Liu and Zhang (2014) proposed four regional CE models, which include enterprise group, social function, urban function, and ecological function. Additionally, there are some other implementation approaches like the “2 +4” model (Wang, 2006), the “Three Level Cycle” model (Xie, 2004), and the “5 + 1” model (Liu, 2005). In general, the essence of all the implementation strategies is trying to achieve the CE model by rationally controlling the scale of economic development and relying on institutional design and technological progress, while the approach of CE implementation is the exploration of specific models at different levels or fields.

In practice, the idea of implementing CE in China is to carry on the “3+1” model under the guidance and promotion of the government, that is, to implement standardized demonstration activities of CE in the three levels of enterprises, regions, and society, and the vein industry, for instance, to establish standardized demonstration bases such as demonstration projects, demonstration cities, and demonstration enterprises, and then promote and popularize the mature CE standards to the whole society.

In China, the standardization construction of CE demonstration actions is the vital foundation and support for the normative development of CE (Wu and Fu, 2016). Since the 1990s, many CE pilot enterprises, industrial parks, and pilot cities have been explored throughout the country, such as the national "urban minerals" demonstration base, circular transition demonstration pilot in the park, and pilot projects on recycling and harmless disposal of kitchen waste. Since 2005, China's CE practice has entered a stage of comprehensive pilot and continuous advancement. The state has approved the establishment of the first batch of 84 and the second batch of 65 CE demonstration sites and has successively issued more than 30 laws and regulations on ecological environment and resource protection (Liu and Li, 2018). In 2011, the National Development and Reform Commission published 60 typical cases of CE in 14 categories at three levels, including regions, parks, and enterprises, and there were a total of 77 national pilot projects and more than 100 national and industrial standards for crucial technologies of CE approved by the National Standards Committee as of 2016 (Pei and Zhao, 2016).

In 2017, the Ministry of Housing and Urban-rural Development (MOHURD) announced the first batch of 100 demonstration counties (districts and cities) for the separated collection and resource-based utilization of rural household waste, requiring each pilot area to carry out the separation and treatment of rural household waste in the light of local conditions (PRC MOHURD, 2017). Subsequently, 46 key cities such as Beijing, Tianjin, and Shanghai were determined to implement domestic waste separation on a trial basis to form a batch of replicable and popularize models (PRC MOHURD, 2018), to establish the waste sorting and treatment system in cities at the prefecture-level and above by the end of 2025 (PRC MOHURD, 2019a). To respond to the increasingly severe problem of solid waste, China started the pilot construction of "waste-free cities" in 2019, laying a foundation for a "waste-free society" (Chen et al., 2019). Through the analysis of the difference in the development level of CE between pilot provinces (cities) and non-pilot provinces (cities) from 2003 to 2016, it is found that the development level of CE in all provinces (cities) has improved significantly, and the development level of CE in pilot provinces (cities) is higher than that of non-pilot provinces (cities) since 2006 (Liu and Li, 2019). Also, it is found that the pilot implementation of rural household waste separation and resource utilization has a significant positive impact on the classification willingness and classification behavior of peasant households (Duan, 2016).

In conclusion, the essence of implementation strategies is trying to achieve the CE model by rationally controlling the scale of economic development and relying on institutional design and technological progress, while the implementation approaches are the exploration of specific models at different levels or fields. In recent years, China’s pilot practical exploration has achieved noteworthy accomplishments. However, there are still many barriers that need to be reduced or removed in the popularization of the CE pilot into the whole society. Especially due to the lack of CE awareness and knowledge and the bottleneck of CE technology development, the overall level of CE implementation in China is significantly lower compared to developed countries. Comfortingly, the goal of university assets, including scientific research assets, educational assets, and campus operation assets, is consistent with the overall strategy of CE implementation in China. Universities could and should exert more influence on CE innovations and development.

Overview of main drivers and barriers in CE implementation. To further explore the potential of universities in promoting the transition to a CE model, it is necessary to systematically review the drivers and barriers to CE implementation to find out the main factors that promote and hinder the CE transition (Qu et al., 2022). This study mainly employs a mixed analytical method of bibliometrics and qualitative content analysis on the extant relevant literature. Bibliometrics is used to analyze and process the collected data with the tolls of Citespace and other data analysis techniques so that the results can be visualized, while content analysis is mainly used to classify the critical variables in literature.

- Research procedure. The procedure of this study is mainly divided into five steps, see Figure 1.4. The first step is to draw up a plan after browsing relevant literature, and preliminarily deciding the content to be analyzed and the method used. The second step is to carry out a pre-search in the selected database by selecting and determining the search formula in the framework of the research topic. The third step is to formally perform the search and filter the data. The next step is the data processing phase. The downloaded data should be classified and examined, and then the items selected for presentation are processed separately. The final step is the data analysis and result presentation. The results should be presented clearly and concisely in images or tables by adjusting different parameters.

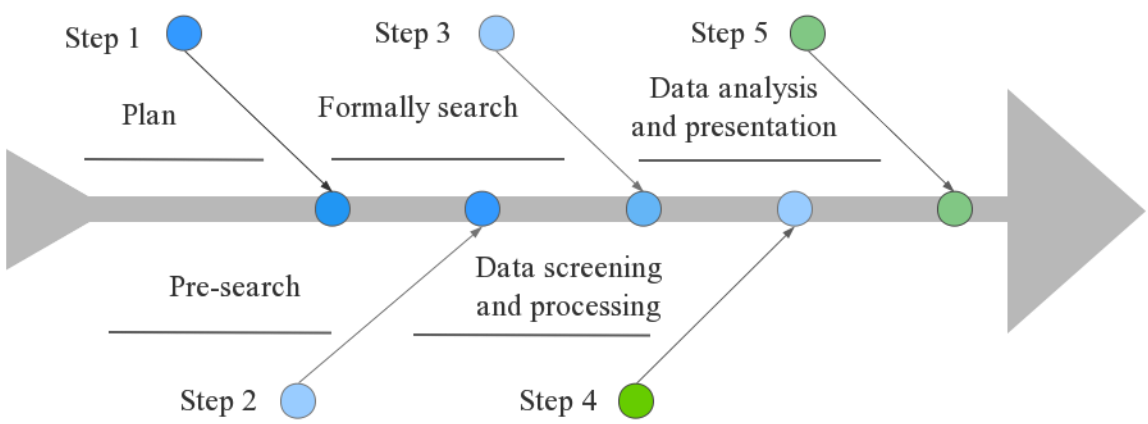

Figure 1.4 - Flow diagram of the research procedure

Source: prepared by the author

- Data collection methods. Selecting comprehensive databases can provide a larger sample for the study to increase the reliability of the results. To ensure that the newest data is included, this study decided to retrieve the publication in CNKI and CQVIP from 2005 to 2021. The year 2005 was chosen as the starting point because the pre-search revealed that the first article relevant to the research topic was published in 2005. Similarly, the timespan this study searched in WoS and Scopus ranged from 2011 to 2021 because the pre-search results show no results on the topic before 2011. The data retrieval time of this study is October 10, 2021. The specific precise search criteria and results can be seen in Table 1.2.

- Databases distribution. Selecting comprehensive databases can provide a larger sample for the study to increase the reliability of the results. Four databases are mainly chosen for retrieval in this study, and the number of the obtained articles and overlaps are shown in Figure 1.5. 215 articles in total are obtained from the WoS core collection and Scopus, 98 of which were repeated in both databases. Similarly, there are 67 articles duplicated in the total of 152 relevant articles retrieved from CNKI and CQVIP. The large proportion of duplication also demonstrates the reliability of our database selection.

Table 1.2 - Specific precise search criteria and results in different databases

Databases	WoS (core collection)	Scopus	CNKI (core periodicals databases)	CQVIP (core periodicals databases)
Search formula	TI="CE" AND TI= (driv* OR bar*) AND DT= (Article OR Review)	TITLE (CE* AND (driv* OR bar*)) AND DOCTYPE (ar OR re)	TI= ‘CE’*(‘driver’+ ‘barrier’)	T=CE AND (driver OR barrier)
Timespan	2011-2021	2011-2021	2005-2021	2005-2021
Data of retrieval	October 10, 2021	October 10, 2021	October 10, 2021	October 10, 2021
Results	104	111	68	84

Source: prepared by the author

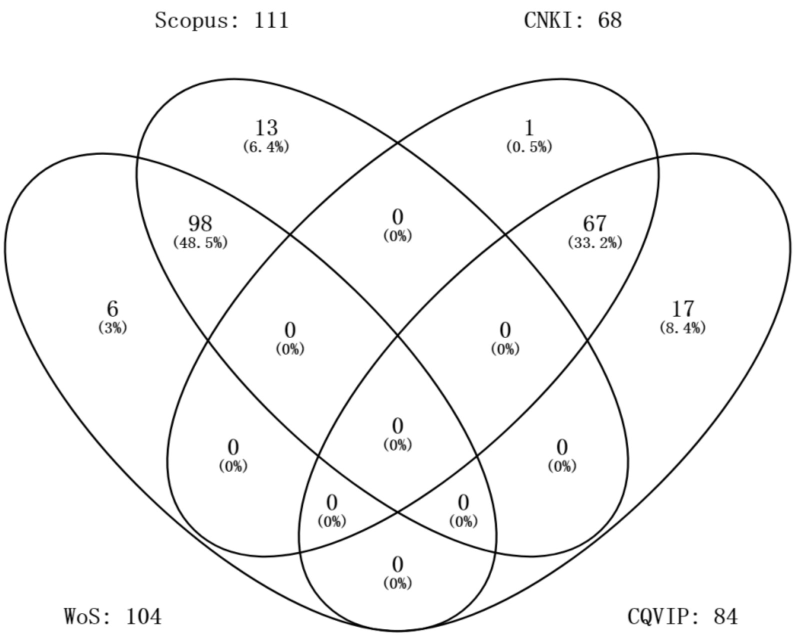

Figure 1.5 - Database distribution of relevant articles

Source: prepared by the author

- Publication and citation status. Through a statistical analysis of the publication years, this study identified the year when the topic-related publications were first published and the year with the most significant number of publications, see Figure 1.6.

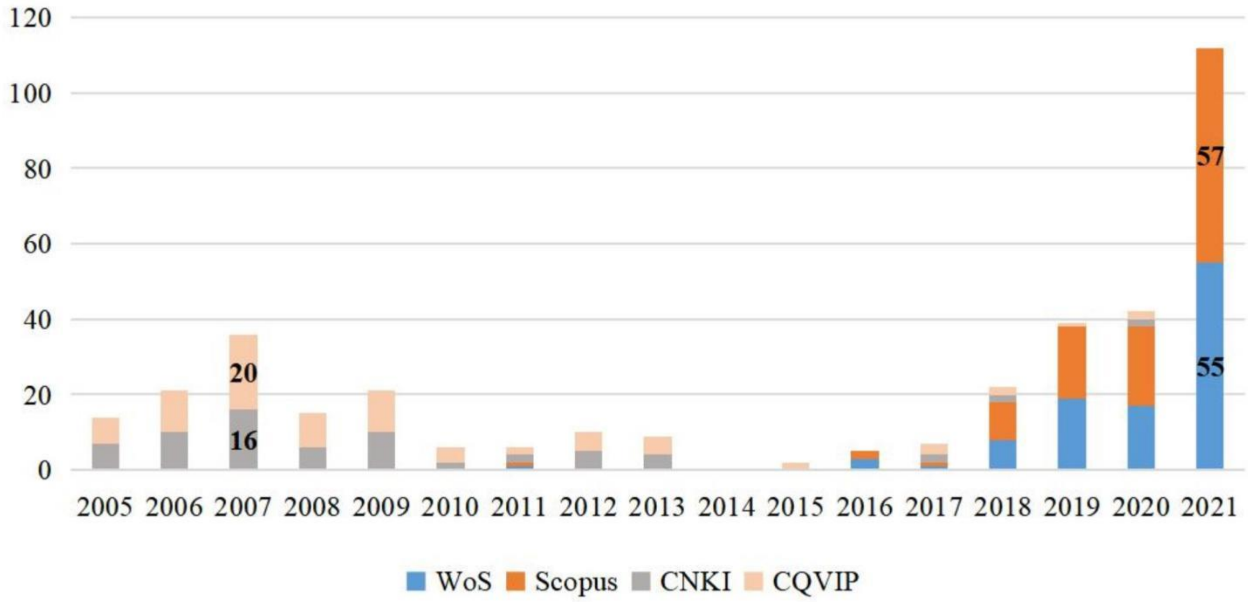

Figure 1.6 - Number of publications in different databases

Source: prepared by the author based on the retrieved results in different databases

The first publication consistent with the topic appeared in 2011 in Wos and Scopus. However, no publications appeared between 2012 and 2015. It was not until 2016 that new articles appeared again, and presumably continued to increase in the following years. The number of publications reached its peak in 2021 (112 articles), indicating that this topic is attracting more researchers' attention. On the contrary, the annual number of articles on this topic shows an opposite trend in the CNKI and CQVIP. The first publication on the topic appeared in 2005. The number of publications has declined yearly since peaking at 36 in 2007. No related articles were published so far in 2021. In fact, this phenomenon is mainly related to the Chinese government's policy on CE. In 2005, China issued regulations to clarify the goal and ambition of realizing the CE goals, marking the comprehensive start of China's CE implementation. Since then, the research on the issues related to CE began to rise, but the enthusiasm gradually decreased again with time.

It is imperative to summarize the number of citations that reflect the importance of the article to a certain extent. As shown in Figure 1.7, there were fewer publications in 2011 and 2016 in both WoS and Scopus, but the number of citations was high. The number of annual citations peaked in 2018, reflecting the emergence of significant literature in 2018. In the meantime, it is also needed to note that articles from the last three years would take a longer time to get a stable number of citations. In CNKI and CQVIP, the peak of citation number appeared in 2006, which reflects that the literature in 2006 was more influential to researchers.

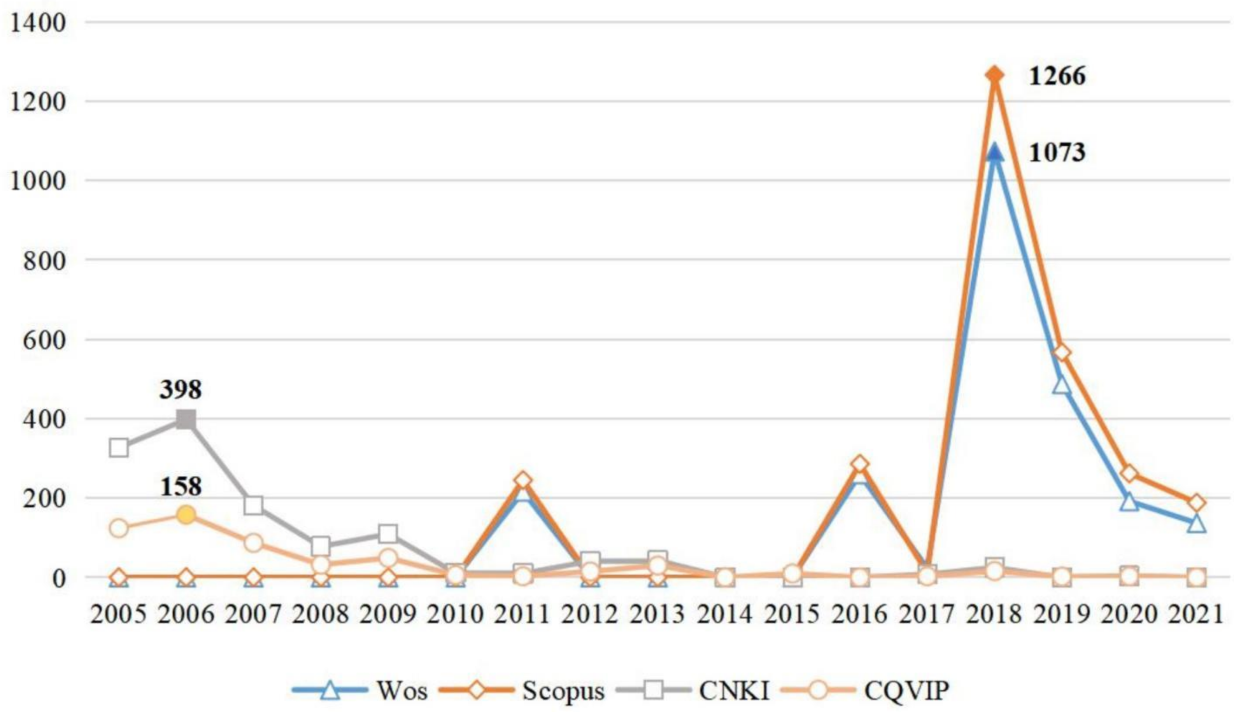

Figure 1.7 - Trends in the number of citations in different databases

Source: prepared by the author

Country distribution. Regarding country distribution, the authors of articles in CNKI and CQVIP are all from China. Therefore, this study conducted statistical data on the articles retrieved from WoS and Scopus to learn which countries in the world have contributed more to the study on this topic, see Figure 1.8. The parameter this study used in Citespace is available in the upper left corner of the figure. To show the results more clearly, this study adjusted the location of the country nodes. The larger country nodes signify the more articles contributed by the country. The outer ring of nodes represents the value of centrality, which reflects the importance degree of literature.

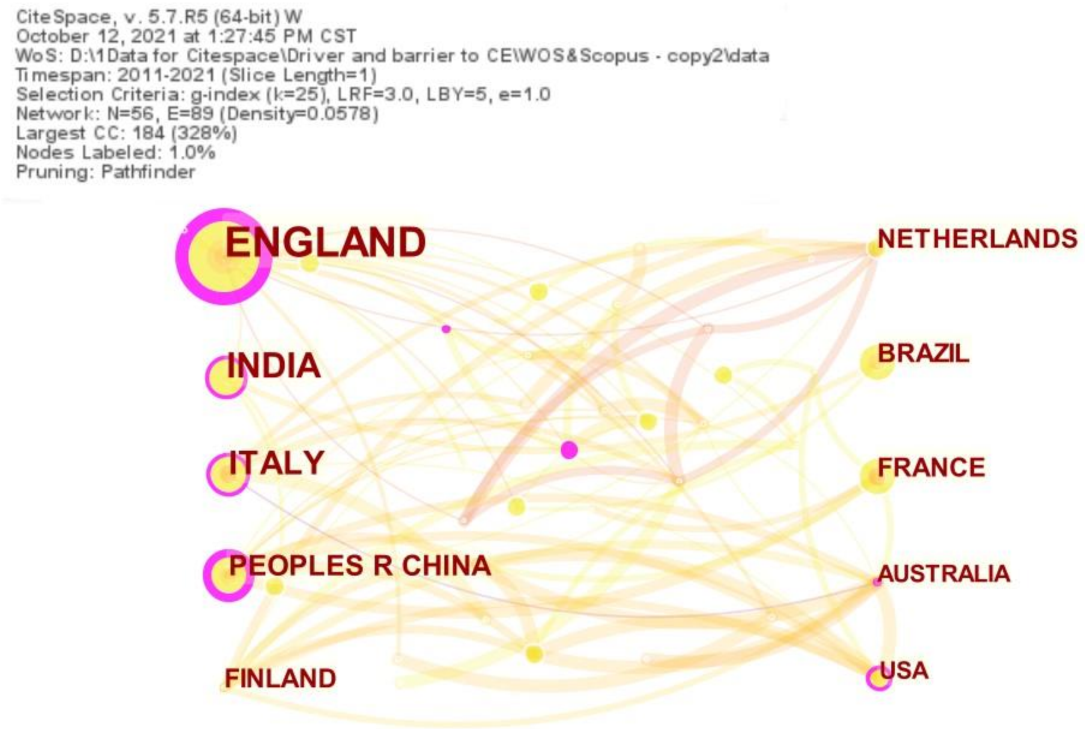

Figure 1.8 - Top 10 countries in publication contributions

Source: prepared by the author

This study put together the list of the top 10 countries by publication numbers, see Table 1.3. England, India, Italy, China, and Finland are the top five countries by publication volume. Both the number of publications (Count=31) and the centrality (Centrality=0.56) of England ranked first. China ranks fourth in the number of publications (Count=9) and second by the value of centrality (Centrality=0.24). It is worth noting that Chinese scholars first published an article on the topic in WoS and Scopus in 2019, while the first article in Chinese databases appeared in 2005. To some extent, this reflects those Chinese scholars have not abandoned their research on CE issues but shifted their publishing direction to international journals. The research on the CE topic has received more and more attention recently. It is necessary to carry out a content analysis of the literature related to China's CE with the times.

Table 1.3 - Top 10 countries in publication numbers

Country	Count	Rank (Count)	Centrality	Rank (Centrality)	Year
England	31	1	0.56	1	2016
India	16	2	0.13	4	2019
Italy	13	3	0.13	5	2011
China	9	4	0.24	2	2019
Finland	8	5	0.10	9	2018
Netherlands	8	6	0.08	13	2016
Brazil	8	7	0.02	23	2019
France	7	8	0.07	15	2019
Australia	6	9	0.12	6	2011
United States	6	10	0.12	7	2019

Source: prepared by the author

- Articles and co-citation network. Based on the data collected from WoS and Scopus, the articles ranked by the total number of citations and the related information are shown in Table 1.4.

Table 1.4 - Top 9 most-cited articles in WoS and Scopus

No	Title	Author(s)	Times
1	Barriers to the Circular Economy: Evidence From the European Union (EU)	Kirchherr, et al., 2018	554
2	Progress toward a circular economy in China: The drivers (and inhibitors) of eco-industrial initiative	Mathews & Tan, 2011	461
3	Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers	Rizos, et al., 2016	452
4	A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective	Govindan & Hasanagic, 2018	434
5	Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy	de Jesus & Mendonça, 2018	397
6	Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe	Ranta, et al., 2018	247
7	Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh	Moktadir, et al., 2018	241
8	Prioritizing barriers to adopt circular economy in construction and demolition waste management	Mahpour, 2018	183
9	Towards a more circular economy: exploring the awareness, practices, and barriers from a focal firm perspective	Masi, et al., 2018	159

Source: prepared by the author

In general, the citation rankings of the articles in WoS and Scopus are different. Fortunately, this study found that the top nine most-cited articles in the two databases were consistent. The final ranking is based on the sum of the number of citations in both WoS and Scopus. There are two studies on China's CE issues in the articles.

To learn the weight of literature and the co-citation network, the co-citation network diagram of literature made through Citespace is presented, see Figure 1.9. The parameters can be seen in the figure. To improve the readability, the threshold of "k" is set to 20. The cited frequency of articles determines the size of nodes and their labels. The larger nodes mean more times that the article is cited. The larger the outer ring of the node is, the higher the centrality is, which also means a closer co-citation relationship between the article and the others.

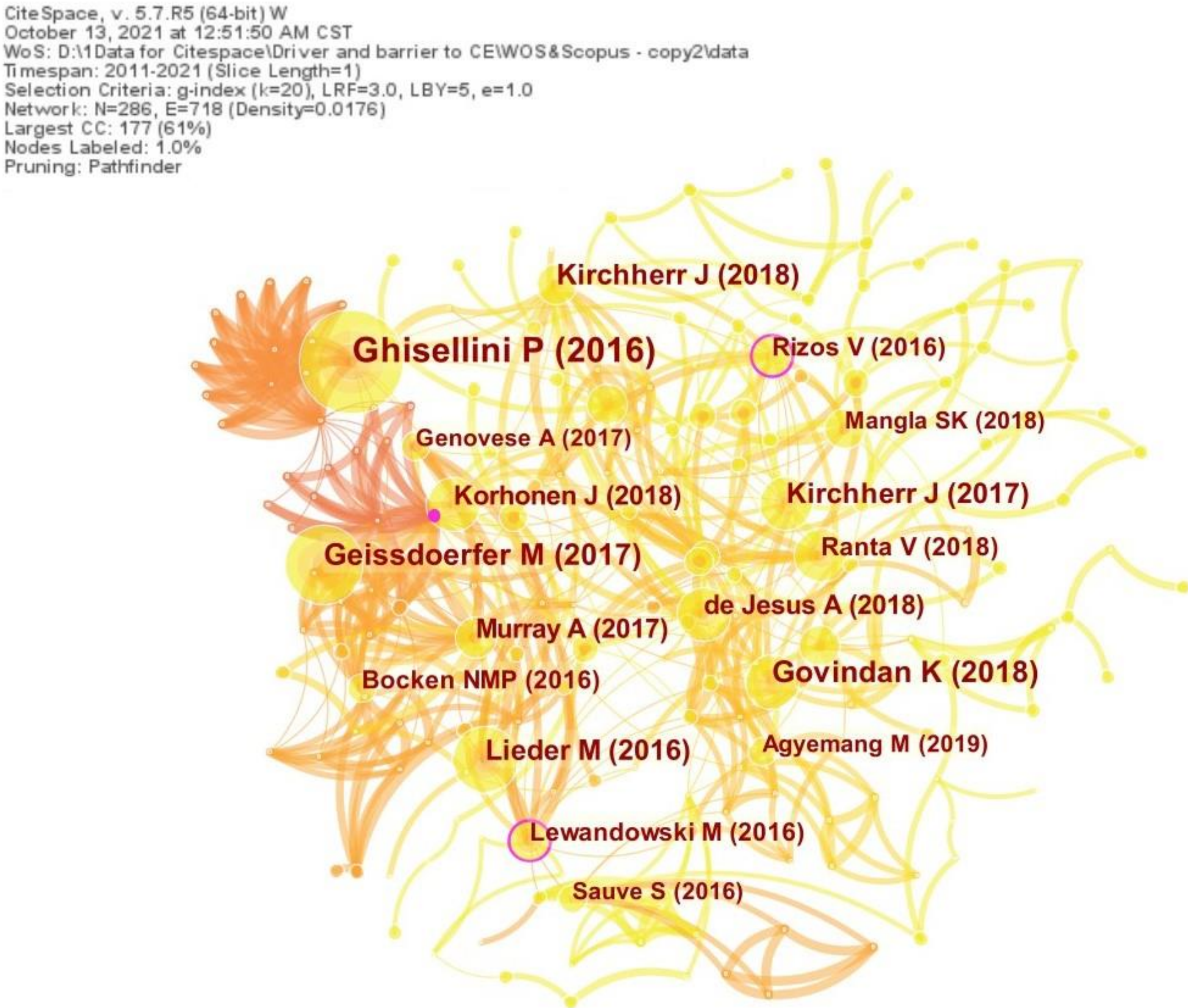

Figure 1.9 - Co-citation network

Source: prepared by the author

Detailed information about co-citation networks can be seen in Table 1.5. The network has a total of 322 nodes and 4742 links. There was a break period from 2012 to 2015. The nodes and links in 2021 made up the most significant proportion of the total, indicating that the research on the topic has received more and more attention recently.

Table 1.5 - Information on the co-citation networks

Year	Criteria (g-index)	Nodes	Exposed Links	Total links
2011	2	21	63	210
2012-2015	0	0	0	0
2016	3	22	66	101
2017	2	21	63	102
2018	5	41	123	400
2019	7	57	171	820
2020	8	58	174	791
2021	15	102	306	2318
Total	--	322	966	4742

Source: prepared by the author

- Main Drivers of CE Model. It is well-known that the development of everything needs to be driven by power, so clarifying the driving mechanism of CE and understanding the drivers of CE are essential to promote the implementation of the CE model continually. The research on the drivers of CE in China mainly focuses on three directions, including driver generation sources of CE, dynamic mechanism construction of CE, and drivers in different industries and fields. Based on the literature analysis, this study constructed the keyword cloud map by summarizing the keywords related to the driver factor in the literature, see Figure 1.10. The size of the keyword font represents the frequency of occurrence, that is, the keywords with larger font appeared more frequently in literature. Through inductive analysis of these 33 keywords summarized in Figure 1.6, this study found that researchers generally believe government policy support, public participation, economic benefits, the awareness and knowledge of CE, and technological support are typically recognized as the main drivers of CE in China. Relevant literature sources for the main drivers are summarized in Table 1.6.

Figure 1.10 - Cloud map of keywords related to drivers

Source: prepared by the author

Table 1.6 - Main drivers in the transition toward the CE model in China

Main drivers	Literature sources
Government policy support	Li D. (2008), Li & Li (2011), Ranta et al. (2018), Zhou H. (2012), Xiao & Peng (2008), Duan (2012), Zhang (2018), Liu (2014), Matus et al. (2012), Mathews & Tan (2016), Ai & Xi (2010), Zhou et al. (2012), Zhou Y. (2012)
Public participation	Zhou H. (2012), Xiao & Peng (2008), Zhang (2018), Liu (2014), Mathews & Tan (2016), Zhou Y. (2012)
Economic benefits	Xiao & Peng (2008), Duan (2012), Ai & Xi (2010), Zhou et al. (2012), Zhou Y. (2012), Liu (2015), Liu & Xiao (2015)
Awareness and knowledge	Ranta et al. (2018), Zhou H. (2012), Guo et al. (2016), Xiao & Peng (2008), Matus (2012), Mathews & Tan (2016), Ai & Xi (2010)
Technological support	Li D. (2008), Zhou H. (2012), Xiao & Peng (2008), Zhang (2018), Liu (2015), Xi & Ai (2011), Zhou et al. (2012), Zhou Y. (2012), Zhou et al. (2020)

Source: prepared by the author

- Main Barriers to CE Model. The drivers of CE are the factors that enable and encourage the transition to a CE, while the barriers to CE are the bottlenecks that obstruct transitions toward a CE (de Jesus & Mendonça, 2018). Researchers have already done a significant amount of study and analysis on the barriers in the implementation process of CE. By summarizing the 30 keywords related to the barrier factor in the literature, this study constructed the keyword cloud map to present these keywords and the frequency of occurrence, see Figure 1.11.

Figure 1.11 - Cloud map of keywords that related to barriers

Source: prepared by the author

The keywords with larger font appeared more frequently in literature. The results obtained through inductive analysis of these keywords are similar to Kirchlerr's classification of barriers to CE (Kirchherr et al., 2018), that is, cultural barriers, market barriers, regulatory barriers, and technical barriers are the main barriers that often struggle to mitigate China's process of CE implementation at present. Relevant literature sources for the main barriers are summarized in Table 1.7.

Among the main drivers this study has identified, China stands out in terms of government policy support. The Chinese government has already issued numerous laws and regulations and devised a series of ambitious plans for achieving the CE target in China's government development plan, which provided sufficient policy support for CE implementation. As for the other drivers of CE, it requires efforts from other enablers, such as higher educational institutions, other than the government, enterprises, and the public. Colleges and universities have the advantage of education and scientific research, as well as the responsibility of serving society, which could and should improve public awareness and CE behaviors, including providing technological support, cultivating professionals, popularizing CE knowledge, and publicizing CE concepts.

Table 1.7 - Main barriers in the transition toward the CE model in China

Main barriers	Literature sources
Cultural barriers	Zhang et al. (2019), Deng et al. (2013), Guo et al. (2016), Wang (2016), Liu et al. (2021), Xia and Ruan (2020), Ranta et al. (2018)
Market barriers	Matus et al. (2012), Kang (2016), Li (2018), Yin & Liu (2012), Wang (2016), Zhang et al. (2019), Xia and Ruan (2020)
Regulatory barriers	Zhang et al. (2019), Matus et al. (2012), Liu (2014), Jiang & Chen (2017), Yang (2017), Deng et al. (2013), Liu et al. (2021), Ranta et al. (2018)
Technological barriers	Matus et al. (2012), Xu et al. (2012), Xu et al. (2016), Xu et al. (2017), Yuan (2013), Andrews (2015), Xia and Ruan (2020)

Source: prepared by the author

In terms of the main barriers, they interact and influence each other, which could be considered nested. Cultural barriers could be most recognized as the main barriers in the transition to the CE model. It is evident that to eliminate cultural barriers in the CE transition need to popularize CE awareness to the public and carry out CE education. To eliminate the market barriers need to develop consumers' cognitive and pro-circular behaviors. To eradicate regulatory barriers need to improve the willingness and ability of the public to participate in the supervision of CE implementation. Also, to eliminate technological barriers need to strengthen the innovation of CE technology research. Anyway, these paths are closely related to the universities with educational and scientific research assets, which could promote or streamline a CE, as well as remove or weaken the barriers that most frequently derail a CE. In summary, higher education has a positive influence on strengthening the drives and eliminating the barriers, that is, higher education has bright prospects in the process of speeding up the CE transition.

1.2 Application and development of CE targets in university assets management

The analysis of practical necessity and feasibility. Theoretical analysis of the nature of China's CE model and the driving force and obstacles of CE point that universities can play a positive role in promoting the transition to CE. In fact, at the practical level, universities' initiatives and efforts in SD lay the foundation for CE implementation. Specifically, the practical necessity and feasibility analysis of universities participating in the CE transition is mainly reflected in the following aspects.

- Initiatives of universities on the green campus. The idea of a green campus stems from the International Conference on Environmental Protection and its related policies and provisions. The 1972 United Nations Conference on the Human Environment (UNCHE) adopted the Stockholm Declaration, which made the first reference to sustainability in higher education. The declaration put forward several related proposals to achieve SD of the environment, such as using an interdisciplinary approach to carry out environmental education at all levels of formal and non-formal education, in and out of school. The Tbilisi Declaration proposed that universities should have a more important responsibility for environmental protection and should add environmental-related content to university degree courses, which is considered to be the most important in the history of the development of environmental education in the world. Since then, many influential international declarations and conferences have widely influenced the implementation of campus SD, calling on universities to educate students on SD based on passing on knowledge. In 1988, the World Environment and Development Report of the United Nations Conference on Environment and Development (UNCED) proposed the concept of ESD, pointing out that ESD should be promoted to improve people's ability to deal with problems existing in environmental development (Sun et al., 2017). The Talloires Declaration, signed by the presidents of 20 famous universities in the association of University Leaders for a Sustainable Future (ULSF), is currently internationally recognized as the most instructive document to promote the SD of universities. The ten-point action plans in the declaration aim to integrate SD and environmental education into the teaching, scientific research, operation, and publicity activities of colleges and universities, which marks the beginning of the construction of green campuses (Adlong, 2013).

In December 1991, the presidents of several universities worldwide and senior representatives of the International Association of Universities, the United Nations University, and the Canadian Association of Universities signed the Halifax Declaration to address the specific challenges of environmental SD. In addition, In 1992, the “Agenda 21” adopted at the Conference on Environment and Development held in Rio de Janeiro took the Tbilisi Declaration as the main line, calling for the formation of SD education that takes into account life, production and ecology, and summarized SD education as towards SD, rebuilding education, raising public awareness and promoting training. In 1993, the Association of Commonwealth Universities (ACU) of more than 400 universities from 47 different countries signed the Swansea Declaration in Swansea, seeking a way for Asian universities, their leaders, scholars, and students can engage and address sustainability challenges appropriately. In 2003, according to the decision of the United Nations General Assembly (UNGA), when United Nations Educational, Scientific, and Cultural Organization (UNESCO) drafted the draft "International Implementation Plan for the Decade of Education for SD (2005-2014)", according to the United Nations' long-term focus on "education" and "SD" Two areas, further deepening the connotation of ESD (Qian et al., 2006). The American College Presidents’ Climate Commitment program was launched in 2006. Its purpose is to achieve “Climate Neutrality” of college operations, that is, to integrate climate change and SD into colleges and universities. in teaching, research, and social activities. In recent years, with the release and implementation of the Global Action Programme on Education for SD (2015-2019) (UNESCO, 2013) and the Education Framework for Action 2030 (UNESCO, 2015), ESD has gradually formed a routine operation and evaluation mode in colleges and universities. The development of the SD initiative of universities is shown in Table 1.8.

Table 1.8 - Development context of university sustainability initiatives

When	Organizer	Topic	Sustainability initiatives
1972	UNCHE	Stockholm Declaration	It raised the SD issues in the field of higher education for the first time.
1977	UNESCO & UNEP	Tbilisi Declaration	It suggested that universities should assume more important environmental responsibility and add environment-related content into university degree courses.
1988[1]	UNCED	World Environment and Development Report	It proposed the concept of ESD for the first time.
1990	ULSF	Talloires Declaration	It adopted a 10-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations, and outreach at colleges and universities.
1991	Some universities and associations	Halifax Declaration	It addressed the specific challenges of sustainable environmental development.
1992	UNCED	Agenda 21	It summarized SD education as oriented towards SD, rebuilding education, enhancing public awareness, and promoting training
1993	ACU	Swansea Declaration	It engaged in involving the university leaders, scholars, and students in responding to the SD challenge appropriately.
2003	UNGA	United Nations Decade for ESD (2005-2014)	It deepened the connotation of ESD and pointed out that ESD must consider three areas of sustainability, including the environment, society (culture), and the economy.
2006	Some university presidents	American College Presidents' Climate Commitment	It aims to integrate climate change and SD into teaching, scientific research, and social activities of universities.
2013	UNESCO	Global Action Programme on ESD (2015-2019)	It aims to generate and expand education for SD and accelerate the process of achieving SD.
2015	UNESCO	2030 Framework for Action on Education	It aims to ensure that ESD exists at all levels and in all forms of education and that all learners acquire the necessary knowledge and skills to promote SD by 2030.

Source: prepared by the author based on official website data and information

Tsinghua University is the first university in China to put forward the concept of a green campus, and also the first to propose the construction of a green campus. Later, more colleges and universities joined the ranks and carried out the practice of green campus construction. In 2011, Tongji University, Zhejiang

University, Tianjin University, and other institutions jointly launched the “China green campus Alliance” to lead and promote the development of green campus construction in Chinese universities. However, at present, although sustainable university construction has been carried out in China for several years, there are only a few universities that have constructed and implemented the working framework of sustainable university at the level of system management and strategy, and the construction of sustainable university is still at the initial stage.

- Legal provisions on the university CE responsibilities. In China’s laws on CE, the status and responsibility of colleges and universities in developing CE are stipulated. The CE Promotion Law (PRC SC, 2009) stipulates that the government, enterprises, public institutions, and all citizens should take measures to improve the level of waste utilization and resource recovery and promote the development of CE. The promulgation and CE implementation Promotion Law make the development of Higher education in China face the legal environment of CE. Since the development of CE needs the efforts of the whole society, higher education is obliged to contribute to the development of CE (Gong, 2010).

Subsequent relevant laws and regulations for the responsibility of higher education in the CE implementation for further evident. “Circular Economy Development Strategy and Action Plan” (PRC SC, 2013) specify the feasible scheme for universities, such as strengthening CE education and professional talent training, incorporating CE concepts and knowledge into the curriculum, setting up CE-related majors, and implementing CE training plans. Moreover, the “Circular Economy Promotion Plan 2015” (PRC NDRC, 2015) stipulates that the Ministry of Education and other relevant departments should actively promote CE practice on campus. For example, it encourages universities to carry out energy-saving publicity and education activities, strengthen the training of water-saving counselors, formulate evaluation methods based on actual conditions, and take students’ daily thriftiness and environmental protection behavior as an important reference in evaluating awards and excellence. Also, the establishment of CE-related majors is brought up again.

Therefore, universities have an unshakable responsibility to promote the CE transition. Contributing to the CE implementation is not only the requirement of the CE-related laws for higher education but also the requirement of the Higher Education Law in China for universities.

- **Requirements for the functional evolution of universities.** Before the end of the 18th century, the functions of universities were mainly embodied in traditional teaching, cultivating talents, and disseminating knowledge through education. The first academic revolution triggered by the Humboldt Reform in Germany in the early 19th century made universities undertake the mission of scientific research, so universities began to have the dual functions of talent training and scientific research. In the century, the silicon valley phenomenon of Stanford University led to the second academic revolution, after which the entrepreneurial function of the university was born, so universities have three functions including talent training, scientific research, and social service (Etzkowitz, 2004). Correspondingly, two academic revolutions have created two new university models, investigative university, and entrepreneurial university, as shown in Figure 1.12. With the development of society, the functions of universities are also evolving.

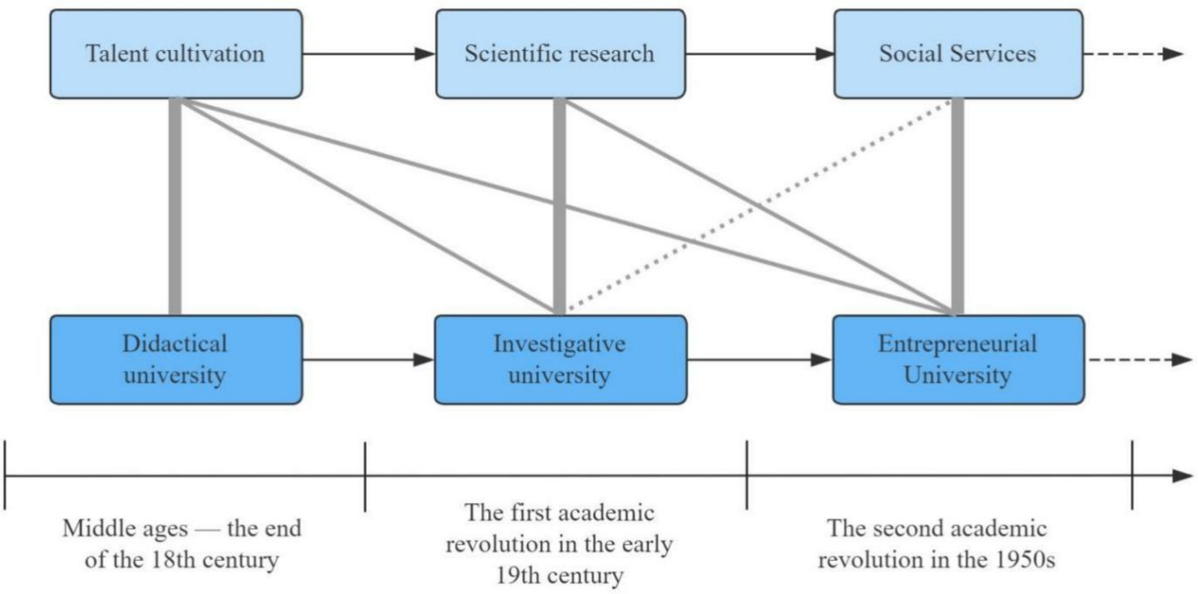

Figure 1.12 - The evolution of university functions

Source: prepared by the author based on Etzkowitz (2004)

In 1991, the Halifax Declaration made it clear for the first time that universities have three roles which include education, research, and public service, which enable them to contribute effectively to the SD of society. In fact, the function orientation of colleges and universities also determines that colleges and universities must be one of the main bodies of developing CE and should actively carry out theoretical and practical exploration of CE. The function of education can realize the education of CE concept and knowledge and the training of specialized talents, and provide human resources guarantee for the CE implementation. The scientific research function helps construct the scientific and technological support system of CE and provides guarantees for CE implementation. The function of social service once again clarifies the social attribute that education should serve for social development, to build a resource-saving and environment-friendly society by actively carrying out CE practice on campus.

- Needs to inherit and develop the ecological civilization. In the process of human civilization, agricultural civilization and industrial civilization have played an essential role in promoting the improvement of human life quality and social scientific and technological progress. However, agricultural civilization and industrial civilization lost the binding force of ecological friendliness, resulting in the rapid development of the economy and society, while bringing about the destructive results of ecological environment deterioration. At the same time, it also intensifies the contradiction between man and nature and limits human existence and the SD of society. Ecological civilization is a necessary condition for the perfection and SD of industrial civilization and agricultural civilization. It overcomes all kinds of drawbacks and defects brought by the development of traditional agriculture and industry. Ecological civilization can not only correctly handle the relationship between humans and nature but also make the relationship sustainable and harmonious, and finally realize the SDGs of economic development, social progress, and sound ecology.

CE is the internal and realistic requirement for promoting ecological civilization construction. For China, a country with a large population and low per capita resources, the traditional path of industrialization not only makes economic development challenges to sustain but also destroys the ecology and environment, directly hindering the improvement of people's quality of life. In addition, the development of CE is the primary way and essential content of ecological civilization construction. As a new economic development model of protecting resources and the environment, CE can fundamentally alleviate the contradiction of resource constraints, help coordinate the relationship among society, economy, and resources and environment, and improve the quality of economic development.

Therefore, CE is not only an economic growth model and social consumption model, but also a cultural model (Feng, 2006), which contains the material wealth and spiritual wealth created by human beings on the concept, practice, achievement, and experience of CE. As seen from the development course of CE, it was first introduced into China after the rise of western developed countries. In this process, Chinese people wake up after the excessive consumption of resources and environmental pollution in economic development. Truth from facts, the current circulation economy in China's dissemination has not been prevalent. Therefore, the task of promoting the process of ecological document construction through the implementation of the recycling economy undoubtedly falls on higher education, which takes the dissemination of new knowledge and new technology as its responsibility.

- Needs of scientific development of higher education. The establishment of the CE concept in national development is bound to bring about an impact on the needs of talents and the development direction of scientific and technological innovation. The development strategy of higher education only serves the plans of national economic and social development, which can exert the influence of higher education in promoting national economic and social development. The development strategy of higher education can fully exert the strength of higher education and make the most immense contribution to promoting national economic and social development only if it is a strategy that serves the country's economic and social development. Gong et al. (2010) argue that the development strategy of higher education should be adjusted according to the concept of CE, implementing CE human resources strategy, implementing CE discipline construction and general education, and building CE campus culture, so as to realize the scientific development of higher education. Therefore, the construction of green campuses with the concept of SD has become a trend in many colleges and universities. For example, Tsinghua University, the first "green campus" in China, has put forward the plan of building a “green campus” since 1998 and has formed a green campus construction mode with green education, green scientific research, and green campus as the core contents.

In addition, universities implementing CE practices can potentially reduce corruption and unethical practices by making it easier to conduct accurate supply chain audits, select ethical suppliers, and encourage unscrupulous suppliers to change their practices (Andrews, 2015).

Review of the contributions of universities to CE performance. As the engine of knowledge and technology, the dominant role of universities in carrying out education for SD has been widely recognized. Researchers from all over the world have conducted extensive research on the contribution of universities to CE. The previous related research mainly focuses on the following aspects.

- Construction and talent training model of CE-related majors. Cui et al. (2018) investigated the current situation and development advantages of the Resource Recycling Science and Engineering (RRSE) major at universities, and explored the necessity, training objectives, and construction modes of this major. Liu et al. (2017) constructed the curriculum system aiming at talent cultivation through the investigation and research on the talent demand of local economic construction and the talent cultivation program of the RRSE major in various universities.

Gong et al. (2010) highlighted that higher education development strategy should be adjusted in terms of the CE concept, implement the human resources strategy of CE, enforce the discipline construction and general education of CE, and build a CE culture on campus to realize the scientific development of higher education. Xia et al. (2015) justified that in the context of collaborative innovation, the resource recycling science and engineering discipline of local colleges and universities should take the combination of political, industry, university, research, and application as the important breakthrough point to provide talents and intellectual support for regional economic and social development.

- Explicit and implicit curriculum design of CE. Andrews (2015) agued the knowledge and ability to apply the principles of the CE must be embedded in the curriculum so that they also become integral to design practice. In his opinion, not all students will embrace design for SD but it is no doubt that teaching them about the CE will enable sustainability issues to be addressed implicitly. Leubea and Walcherb (2017) argued that circular product design is the key problem to making the shift towards the CE and appealed to renew the curricula of design schools.

Nunes et al. (2018) reviewed the environmental activities of 50 universities ranked highly in terms of their environmental credentials or their environmental science courses and then presented how universities can affect material flows, promote sustainability outside of the formal curriculum, and act as catalysts with business. Kopnina (2019) presented a literature review that describes the application of circular methodologies to education for sustainability, which has been slow to adopt circular systems to the curriculum, and discussed how Bachelor and Master level students apply their understanding of these frameworks to corporate case studies.

Fonseca et al. (2018) used a systematic review utilizing a structured approach to analyze Portuguese higher education institutions' BSc and MSc courses and the content analysis of their curricular units and found that sustainability is covered in most Social Sciences, Engineering, and Management, BSc, and MSc courses, offered by the top 8 Portuguese Higher Education Institutions, but the Education for SD was lacking a consistent body of knowledge. Hall and Colby (2018) argued that a CE approach to curriculum design can motivate deep learning, through experimental practice, deep-dive research, and systems thinking, and provided a structural framework of a CE agenda to the fashion education curriculum, establishing a novel approach that could be applied to other specialist fashion education institutions. Yao (2006) argued that universities should advocate CE as an elective course, so as to enable students to participate in CE activities at the ideological, behavioral, and practical levels.

- Instruction approaches and tools. Appropriate teaching methods can have a positive impact on learners' attitudes and motivation (Sugano & Mamolo, 2021). All of the extant literature on education for CE is grounded in various learning and teaching theories. Pedagogical principles of constructive alignment and problem-based learning have been applied to CE curriculum design. For example, Kirchherr and Piscicelli (2019) developed seven exercises for ECE to introduce undergraduates to the CE concept, which includes a drill game, buzzword bingo, a teardown lab, an eco-industrial park simulation, policy instruments, a circular party, and circular futures. Whalen et al. (2018) advocate for experiential learning by using a serious game that supports holistic and transdisciplinary thinking for a CE. Also, participatory teaching and interactive teaching are adopted as core design principles for CE introductory courses (Kopnina, 2018)

Besides, Andara et al. (2018) carried out a survey on a sample of 189 students to test their current sustainability literacy and created four annual pathways along the roadmap to develop sustainability skills during the four-year college course in engineering, which includes promotion of a recycling campaign through a CE, creation of educational videos regarding sustainability, reinforcement of reasoning and argumentative skills by preparing a debate on environmental issues, and preparation of the students to apply environmental management models to solve sustainability issues within the company. Xue et al. (2018) summarized the problems encountered in the teaching process of the professional elective course Clean Production and CE, and proposed countermeasures to improve the teaching quality from the aspects of textbook construction, case base construction, and diversified teaching methods.

- CE practice activities on campus. The role of the logistics staff in implementing the education for SD with extra-curriculum activities has attracted the attention of some researchers. Fiselier et al. (2018) presented evidence from an online questionnaire survey and in-depth semi-structured interviews and found that the main challenge higher education institutions face is the engaging staff that may question the relevance of the ESD concept, and that lack an understanding regarding its implications for their discipline, while the critical success factors identified are institution-wide people support, high-level institutional support, and funding. Slobbé et al. (2017) conducted a card-sorting activity among 36 foodservice staff to identify the dominant perspectives held by them about the desirability and realities of fostering environmental education in their workplaces and argued that buy-in from food service staff at university is critical for realizing the potential to foster environmental education in a non-classroom setting and so could have the power to benefit communities through producing environmentally literate graduates.

Tan and Li (2016) investigated the campus water consumption, water price, water supply, and drainage of Guangzhou College of South China University of Technology, and discussed the feasibility of water resource recycling on campus. He et al. (2015) discussed the current situation of recycling old textbooks and other cultural resources in colleges and universities and put forward feasible suggestions for recycling secondhand cultural resources. Zou et al. (2018) presented the optimal model of express packaging recycling because of the increasing problems in campus express packaging.

Zhang et al. (2018) argued that the "ternary and secondary classification system" of household waste can be popularized on college campuses, and summarized two feasible paths in practice, one of which is to set up an innovation team to carry out pilot work in some areas of the campus and the other is to set up a demonstration base for household waste separation and wet waste recycling. Lou et al. (2015) discussed the application of reverse logistics operation mode in e-waste treatment on college campuses. Shevchenko and Qu (2019) proposed that the college campus bike-sharing operation system should be constructed in compliance with CE principles to reduce the waste of bicycle resources.

Through comparative analysis of the existing literature, it can be highlighted that there is a lack of a comprehensive and systematic framework of university CE activities in the previous research. That is, University CE activities are fragmented and disconnected from each other and lack a system that can integrate them for an augmented effect. To bridge this gap, this study will integrate various isolated CE activities to build a systematic CE theoretical framework in universities, and attempt to propose a management model to transform this theoretical framework into practice.

Theoretical basis of CE-oriented university management system. Although researchers are full of enthusiasm for the study of CE activities in colleges and universities, there are few pieces of research on the university management mode towards CE mode. The assumption of the construction of CE university management mode in this study is mainly based on the basic functions of universities, integrating and effectively managing all resources conducive to CE implementation in universities, so as to promote the implementation process of CE in the whole society. On the one hand, promote CE education for college students and radiate education to the community, cultivate the concept of CE for college students and residents, and the awareness and accomplishment of taking the initiative to participate in CE activities. On the other hand, the interaction between universities and enterprises should be enhanced, and the technological knowledge spillover from universities to enterprises should be utilized to improve the innovation efficiency and ability of enterprises, thus promoting the CE transition of enterprises and society. In addition, campus CE practice can not only improve the use efficiency of assets, but also establish regional environmental respondents of energy conservation and emission reduction, thus influencing the practice process of CE in communities, cities, and the whole society.

- Transformative learning theory. University CE activities are fragmented and lack a system that can integrate them for an augmented effect. Also, there is no necessary correlation between higher education performance and sustainable behavior in society (Orr, 2002). Therefore, if universities want to improve the efficiency of the implementation of the CE, it is necessary to cultivate and pursue CE values and mindset that can completely change the inherent thinking and operation patterns of the linear economy. To this end, transformative learning is a credible alternative to solving this problem, because the effect in the field of adult education has been proven (Sokol & Shaughnessy, 2018). Furthermore, the significance of transformative learning in ESD has also been confirmed (Burns, 2018). Transformative learning implies profound structural changes in the basic premises of thought, emotion, and behavior, and such a change in consciousness would dramatically and permanently alter self-cognition and our way of being in the world (Sterling, 2010-2011). In other words, different from the traditional manner of knowledge imparting and idea instilling, the CE concept and values can be internalized in the mind and manifested in practice through transformative learning.

To better understand the connotation of transformative learning, Bateson's hierarchy theory of learning should be reviewed. According to Bateson, learning should be separated into three levels, embracing learning, meta-learning, and epistemic learning (Blake et al., 2013). At present, the formal education implemented by higher education institutions generally advocates the first level of learning, which aims to improve intelligence by imparting knowledge through transmissive pedagogy (O'Neil, 2018). Meta-learning refers to the critical assessment and inspection process of the connotative ideas behind the learning content, which could cause changes in the beliefs and values of the subjective world. Epistemic learning is the process of thoroughly reconstructing the paradigm of learners, which will bring changes in people's worldviews and the way they get along in the world. The three learning levels range from low to high, where the higher-level learning experience affects the mindset and action of lower-level learning, see Figure 1.13.

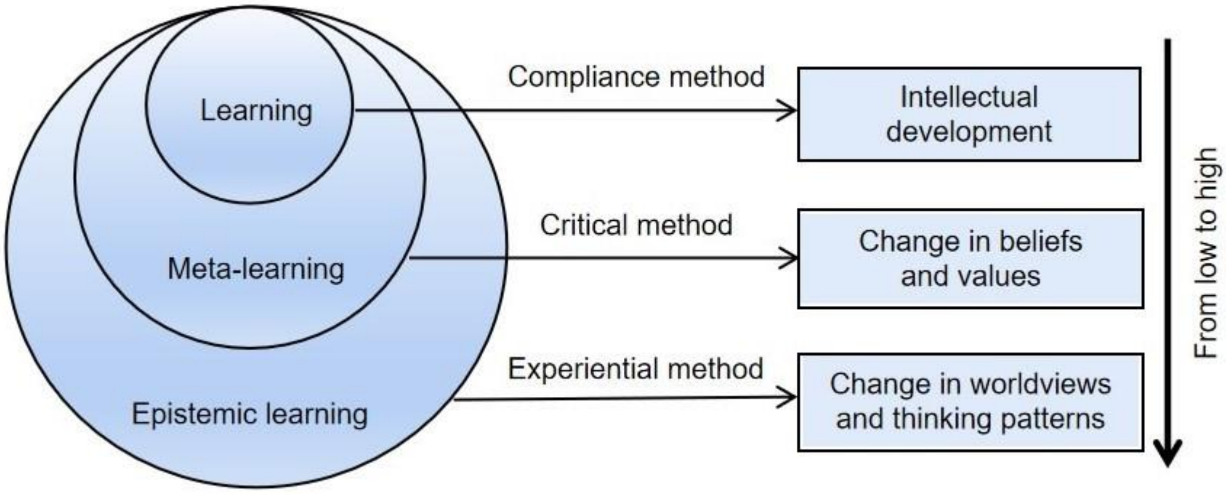

Figure 1.13 - Hierarchy of learning and the transition of different levels

Source: prepared by the author based on Blake et al. (2013)

That is, the first level of learning is far from sufficient to establish CE values and patterns for improving the performance of CE education in universities. Higher levels of transformative learning and education are needed to improve the quality of CE education in universities, which not only could help learners acquire knowledge but also make them internalize CE values in their worldview and epistemology to stimulate the natural occurrence of pro-circular behaviors. With the combination of theoretical learning and practical experience, constructing a systematic CE theoretical framework in universities is a significant approach to realize transformative learning and education, which could integrate various isolated CE activities, thus enabling university administrators and students to change their epistemological presupposition and behavioral patterns to make the universities' effect truly prominent in promoting the implementation of the CE.

- SD theory. From the perspective of demography and economics, there are ecological boundaries in the scope of human social and economic activities, that is, the material basis for human consumption is limited, not endless (Agbedahin, 2019). The population is growing and consumption is increasing, while resources are decreasing and pollution is getting worse, restricting the growth of production. Many scholars in their key publications, such as Limits to Growth by Meadows et al. (1972) and Silent Spring by Carson (1994), have advanced the view of the unsustainability of human economic activity, leading to the global debate on the dangers and sustainability of human activities. Although with the development of human science and technology level and technological innovation ability, technological progress and innovation can not only promote production but also alleviate human consumption of the earth’s resources and damage to the environment. This role has a certain limit and cannot solve the problem fundamentally. People need to explore new models, ideas, and theories that can promote the SD of the human economy and society. This is the origin of SD theory.

The term SD was first seen in the “World Nature Conservation Outline” published in 1980. In the outline, two issues of “SD of mankind” and “SD of the earth” were carried out for global SD. Aspects of exploration, recognizing the basic relationship between nature and society, economy. In 1983, the United Nations World Commission on Environment and Development proposed the basic program of SD to formulate a global SD reform program and timetable. Then in 1987, the Global Commission on Environment and Development released the report “Our Common Future”, which defined SD as Pareto-optimal development, and proposed a short-term “Millennium Declaration” goal (2015), two-generation SD transition goals (2050) and long-term large-scale transition goals (after 2050), and systematically expounded the content of SD.

The widely accepted definition of SD refers to “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (McKeown, 2002; UNESCO, 2014). This interpretation of SD was widely used on a global scale and had a profound impact. The concept of SD can be divided into two levels. First, it is a development that meets people’s needs, and the normal needs of present and future generations should be met and guaranteed. The second is to limit normal or irrational needs. It means putting the well-being of all mankind first, and effectively limiting and containing the unreasonable and inexhaustible demands of the present generation. Only in this way can it ensure the reasonable needs of future generations.

The emergence and dissemination of the concept of SD and related theories can be called a major change in the ideology in the development of human society, and it has had an important impact on people's thinking and behavior in a civilized society. At present, the theory of SD has become the basic theory to guide economic and social development. The development of CE is an important way to achieve SD, and it is also a fundamental means to protect resources and reduce environmental pollution. With the new vision of ESD as a kind of education giving everyone the responsibility to create a sustainable future (UNESCO, 2005), the SD theory has also become a guiding theory for colleges and universities to build a campus management model towards a CE.

- Public participation theory. Public participation in social governance and various public management decision-making and implementation is an important symbol of modern civilized society. The satisfaction and participation level of public participation in social governance are closely related (Fu &Tu, 2014). Likewise, the goals and actions of CE must rely on the maximum recognition, support, and participation of the public and social groups. The way and degree of participation of the public, groups, and organizations will determine the progress of the realization of CE development goals. Therefore, public participation is also a necessary guarantee for realizing the CE transition. Public participation in CE should be comprehensive, including participation in the decision-making and monitoring of the implementation process of activities.

It is of great practical and practical significance to focus on the cultivation of political participation awareness and the awareness of participating in CE since the student days. In the management mode and organizational structure of colleges and universities towards CE, the way and degree of participation of various stakeholders in management are like that of public participation. Therefore, the theory of public participation is also an important theoretical basis for colleges and universities to build a campus management mode toward CE. In the field of research, Arnstein's ladder theory of public participation is a typical example.

The Ladder Theory of Public Participation (Arnstein, 1969) believes that the essence of public participation in decision-making is the public's knowledge, discussion, evaluation, and influence on the decision-making process and decision-making content. Public participation in different decision-making modes reflects different levels of public participation, which are composed of different ladders from low to high. At the bottom of the trapezoid, the public does not have any power, including the right to speak, and can only passively accept the decisions of managers. When the trapezoid moves upward, the public can receive limited information in this area and have a certain right to know. Moving up again, in this area, managers and management departments will solicit relevant opinions and suggestions from the public for reference, and the final decision-making power remains in the hands of managers and management departments. Participate" stage. Moving up again, the decision-making power and weight will be further transferred to the public, and by analogy one by one, it will eventually reach the control of the public. At this time, the public has completed decision-making authority, and managers and management departments become service departments. According to Arnstein's theory, the International Association for Public Participation (IAP2) divides the level of public participation into three levels: no participation, low degree of participation, and high degree of participation, as shown in Figure 1.14.

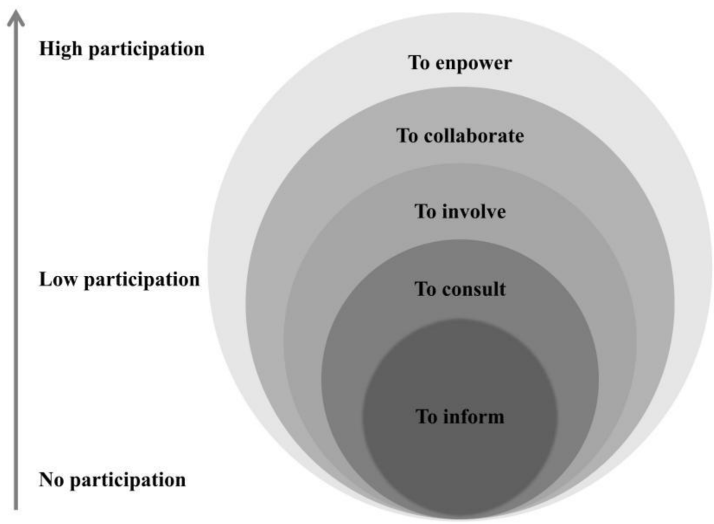

Figure 1.14 - Comparison of the scope and degree of public participation

Source: prepared by the author based on the website of IAP2 (2007)

Studies in the field of environmental governance show that the effect of environmental governance varies with the degree and stage of public participation in China's environmental governance. If the public participates in project decision-making and environmental impact assessment in advance, the environmental governance effect can be improved more effectively (Xue & Dong, 2010). Therefore, according to the public participation theory, the degree and stage of participants' participation in university management toward CE are closely related to the management effect.

- Knowledge spillover theory. University CE activities, including education, scientific research, and campus practice, will have a positive impact on the development of CE in the whole society. In essence, the contribution of universities to CE is the positive externality to the production and life of the community, city, and whole society through the overflow of university knowledge. Therefore, knowledge spillover theory has a strong practical and instructive significance for university management oriented to CE.

Foreign scholars have long recognized that regional innovation and economic activities have spatial connection and agglomeration. Krugman (1991) first proposed that new economic geography would have an important impact on regional economic activities. It emphasizes the role of externalities in the spatial agglomeration and regional economic activities (Grossman & Helpman, 1991). Knowledge Spillovers refer to imitative innovation and gaining more benefits from other imitated innovation research, which reflect the diffusion of information and ideas between neighboring knowledge producers, strengthening spatial agglomeration innovation (Audretsch & Feldman, 1996). The regional knowledge spillover framework speculates that because tacit knowledge is more easily transmitted, including face-to-face interaction, geographical proximity and innovation agents lead to greater knowledge spillovers (Henderson, 2007). From the perspective of economic development, the exchanges and cooperation between the two neighborhoods increase the total knowledge stock of the region, improve the knowledge reserve of the public and the knowledge level of enterprises, enable the development of more differentiated products, and promote the endogenous economic growth (Romer, 1990).

Using European patent data, the empirical study shows that R&D expenditure in the neighboring region will affect the patent activity in the region, so it can be seen that regional innovation will improve the innovation capacity of the neighboring region (Bottazzi & Peri, 2003). It is traditionally believed that knowledge spillover is spatially limited, and knowledge can only be transmitted effectively within a certain range of content. However, with the increase in distance, the effect of knowledge spillover will decrease (Sjoholm, 1999). Relevant empirical studies show that the measurement of knowledge flow using patents shows strong spatial attenuation (Jaffe, 1993). In regional innovation, there exists a three-helix space consisting of knowledge space, convergence space, and innovation space (Herry, 2002).

- Cognitive behavior theory. In the university management mode towards CE, the ultimate goal of the popularization and promotion of CE behavior is to achieve the full participation of all teachers and students, especially the positive CE behavior of college students. Theoretically and empirically, it is of great practical significance to explore the influencing factors and promotion paths of CE behavior of college students. The research on the influencing factors of CE behavior can be based on the relevant theories of environmental behavior research. One of the more popular theories is Ajzen's Planned Behavior Theory (Ajzen, 1991), which holds that individuals' behavioral intentions are shaped by their attitude toward behaviors, subjective norms, and perceived behavioral control. In addition, another widely used theory is Stern (2000) and his colleagues (Guagnano et al., 1995; Stern et al., 1999) developed an ABC "Attitude - Behavior Context" (ABC) comprehensive model of environmental behavior, see Figure 1.15.

According to Stern, environmental behavior (B) is generated by the interaction of individual attitude variables (A) and situation factors (C) towards environmental protection. When the external factors have a neutral influence, the environmental attitude has the strongest influence on environmental behavior.

When the external factors are positive or negative, they exert the same influence on the attitudinal behavior path. The attitude variables considered in this theory can include a variety of specific personal beliefs, norms, and values, as well as a general "tendency" to act in a certain way. Background factors can include a variety of influences, such as monetary incentives and costs, physical capabilities and constraints, institutional and legal factors, public policy support, interpersonal influences (such as social norms), and broader social contexts such as loyalty to or being influenced by environmental groups.

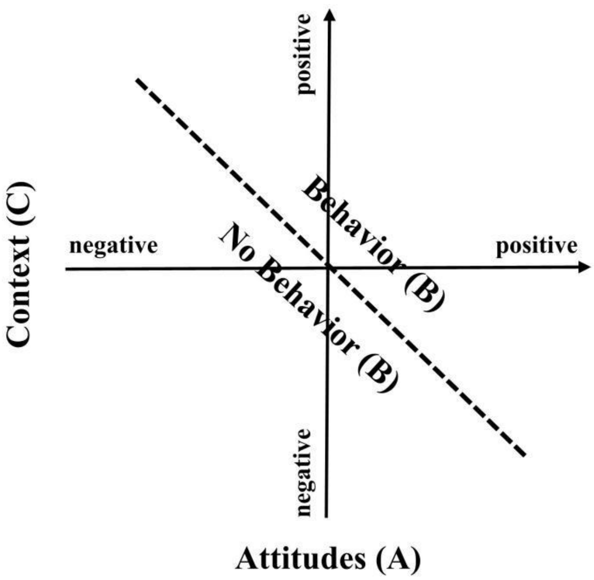

Figure 1.15 - The Attitude - Behavior - Context model

Source: prepared by the author based on Stern (2000).

A survey of the British public shows that environmental values have a significant impact on the public's environmental behaviors such as waste recovery, reuse, and reduction (Barr, 2003). The relevant research shows that individuals' environmental attitude has the highest correlation with the degree of participation in environmental behavior (Wang, 2013). In the survey and research on the environmental attitudes and behaviors of the American public, there is also a significant relationship between individual environmental attitudes and their environmental behaviors and participation in environmental protection (Brent, 1996). The investigation and analysis results of Switzerland show that knowledge and environmental values partly explain environmental behavioral intention, while environmental behavioral intention mostly explains environmental behavior (Kaiser, 1999). From the integration of research literature on environmental behavior (Hayes, 2001), it can be seen that environmental knowledge, knowledge of environmental action strategy, and the sense of responsibility have a significant impact on environmental willingness, and thus on environmental behavior. In addition, some studies have shown that the public's environmental willing-behavior path is affected by situation factors, that is, situation factors will have a positive or negative adjustment effect, and will promote or inhibit environmental behavior accordingly (Guangnano et al., 1995).

In the study of students' environmental willingness and environmental protection behavior, the investigation of American primary school students also confirmed the positive correlation between environmental knowledge and environmental protection activities (Rockland, 1995). However, studies on the relationship between willingness and behavior showed that when the behavior required participants to pay higher effort, willingness would have a strong influence on the behavior, and vice versa (Schultz & Oskamp, 1996). Under the condition of similar environmental cognition and responsibility, college students in areas with better environmental protection have a more active willingness to participate in environmental protection (Richard & Adams, 2011).

In short, specific behaviors are the result of interaction between internal (knowledge, values, attitudes) and external (ecological society) factors. Effective interventions, then, can promote environmental behaviors under the influence of these internal and external factors. Therefore, it is necessary to verify and analyze the variable relationship among college students' CE consciousness, behavior, and situation factors, so as to put forward strategies to strengthen CE behavior.

1.3 Review of the sustainable university management system and practical experience in developed countries

Evolution of sustainable management system in universities. The CE activities of universities originated from their initial SD practices, especially the construction of sustainable campuses. Therefore, it is necessary to summarize the research on the international sustainable university management model and operation mechanism in this study. Based on the theory of ESD, the research and practice of green campuses and sustainable university construction have been started very early in the world.

For a green campus, the United States Green Building Council (USGBC) defines it as an optimized higher education community that could achieve improved energy efficiency, resource conservation and protection, and environmental quality through sustainable education. The idea of a green campus explicitly focuses on improving the impact that buildings and the campus have on the environment. To create a green campus, many programs should be put into practice on campuses, such as renewable energy, low-carbon transport, reused water, and recycling. Different from a green campus, a sustainable university always refers to environmental, economic, and social concerns that universities should have as the obligation on their activities in the use of resources (Velazquez et al., 2006). From the point of view of constituent aspects, a sustainable university is an educational institution that educates global citizens about SD (education), offers relevant insights on urgent societal challenges (research), reduces the environmental and social footprints of its campus operations (operations), empowers students and staff to act (Community), and makes sustainability a central priority (governance). Similarly, a university campus environmental management system was first defined as a system with four dimensions, namely education, research, university operations, and external communities Cortese (2003), and subsequently, evaluation and reporting were added as a fifth dimension (Lozano, 2006).

From the comparison of a green campus and a sustainable university, it can be seen that although a sustainable university points to a broader field of SD, the two concepts are relatively close from the perspective of resources and the environment. Both two types of universities regard the principle of SD as the goal of campus management to achieve SD and green development of the economy and society. So their management system and practical experience could be used as the inspiration for this study.

- Environmentally sustainable practices. The sustainability efforts of universities aren't new. Like many other institutions, universities became aware of the impacts that their activity had on the environment. As such, environmental concerns worked as the very first driving force towards sustainability. Energy consumption, for instance, has become the main target of sustainability efforts, because of its relationship to environmental degradation and potential economic savings. Three main approaches have been used to manage environmental issues at universities (Alshuwaikhat & Abubakar, 2008): "Green Buildings Initiatives", ISO 14001 standard, and EU Eco-Management and Audit Scheme (EMAS). The "Green Building Initiatives" approach includes efforts made at the campus' infrastructures, such as reducing building energy and water consumption. while implementing Environmental Management Systems (EMS) (ISO 14001 Standard and EMAS) to manage environmental issues and so to approach sustainability on campus can be classified as "Management Initiatives".

The Leadership in Energy and Environmental Design (LEED) green building certification program is the accepted benchmark for the design, construction, and operation of green buildings in the United States of America. Many universities adopted this certification process to assure their building's sustainability, largely due to the "Green Campus Campaign", which encourages and promotes the use of LEED as a roadmap to greening the university campus. USGBC offers a set of rating systems that can be used by universities in different situations. Like LEED, building research establishment environmental assessment method is another environmental assessment method and rating system widely used in Europe, but also all over the world.

Even though operational initiatives can be seen as worthy examples of sustainable practices, they cannot by themselves be a guarantee of campus sustainability. They lack a systematic and continuous quality improvement approach that is the core of standardized management systems.

Environmental management systems (EMS) have been implemented by many institutions, which include two models the ISO 14001 standard and the EMAS regulation. The ISO 14001 standard is the most popular procedure used to implement EMS within all kinds of organizations, including universities (Price, 2005). The European Union developed the EMAS methodology, a voluntary EMS, under which companies and other public organizations can effectively evaluate, manage and continuously improve their environmental performance.

Though the implementation of a standardized EMS can overcome the lack of systematic and continuous improvement found in the using of “Green Building Initiatives”, there are some possible drawbacks to this approach to sustainability on university campuses, such as lacking strategic planning for sustainability (MacDonald, 2005) and specific environmental performance policies and targets (Alshuwaikhat & Abubakar, 2008), and disregarding social and economic issues (Lozano, 2006)

- From EMS to SMS. Different from environmental management at universities, sustainability management requires organizations to move beyond eco-efficiency into integrating environmental and social goals into all facets of decision-making (Richards &Gladwin, 1999). This integration means universities should take into serious consideration the triple bottom line of environmental, social, and economic output (Shriberg, 2002). In addition, universities are a unique type of organization, as they need to address not only all three dimensions of sustainability (economic, environmental, and social) but also the five dimensions of their organizational activity (education, research, operations, community outreach, and reporting). The system thinking approach could help to identify key leverage points for actions to improve sustainability on campus and understand how particular operational activities may influence the whole management system (Posner & Stuart, 2013).

Based on the empirical data gathered through a literature review and a worldwide survey on the experiences of universities, Velazquez et al. (2006) proposed a comprehensive sustainability management model specifically developed for universities. The model consists of four phases, organized from strategic to more operational fields, and is based on four strategies (Education, Research, Outreach and Partnership, and Sustainability on Campus). The structure of a sustainable university should also include networking with other universities (organizations such as National Wildlife Federation, the University Leaders for a Sustainable Future, or Second Nature), sustainability audits to monitor, analyze, and control the performance of sustainable initiatives, and obedience to the continuous improvement principle of the Deming Cycle (Deming, 1952). Similarly, Alshuwaikhat and Abubakar (2008) proposed a sustainability management model consisting of a framework for a more suitable approach to achieving campus sustainability that could outperform the limitations of traditional environmental management practices. They chose to integrate three strategies into their Campus Sustainability Model, including EMS, public participation and social responsibility, and sustainability in teaching and research. An interesting feature of this model is the explicit reference to the implementation of an EMS as a strategy to achieve sustainability. Both models can be used as a framework to implement sustainable strategies and policies at universities, and these strategies and initiatives consisted in these models could lead to the implementation of a sustainability mission within a university.

The sustainable management practice of colleges and universities has experienced continuous progress and development from built environment certification to EMS and then to SMS. At the end of the day, implementing either “Green Building” and/or “Management” initiatives comes up short when one is talking about a sustainable university. “Green Building Initiatives” lacks a systematic and continuous campus quality improvement approach, while implementing an EMS may excessively focus the university on environmental issues and disregard social issues. Both these initiatives tend to address only the operational dimension of the university system, neglecting education, research, and community outreach. While the SMS models that are built within all four university dimensions make perfect sense in a scientific paper, it is still difficult to be implemented in real-world situations due to multiple reasons such as lack of motivation (Boks &Diehl, 2006) or shortage of financial resources (Velazquez et al., 2005). So, it is worth trying to build a more practical and down-to-earth CE management system in universities compared to SMS.

Operation mechanism and evaluation mode of sustainable universities. In the process of implementing campus sustainable management mode, colleges and universities usually adopt mechanisms and methods including the top-down approach (TDA), the participatory approach (PA), and a mix of TDA and PA. In the dynamic mechanism of EMS, the SD of campus is from implementing standards to implementing standards and then to consciously implementing them. Relevant laws in China have mentioned the responsibility of universities in implementing CE and SD by TDA.

In 2019, the Ministry of Housing and Urban-Rural Development compiled and published the national standard Green Campus Evaluation Standards (GB/T51356-2019) (GCES) based on the original 2013 standards, in which the indicator category reflects the top-down directives for the university, all faculty, and students (PRC MOHURD, 2019b). To promote the construction of ecological civilization in the whole society, the Ministry of Education and the National Development and Reform Commission launched a nationwide Green Campus Construction Action Program (GCCAP) in 2020, which stipulated the goal requirements of achieving at least 60% green campus by 2022. However, due to the lack of clear incentives and participation mechanisms, the process of green campus construction in colleges and universities is still slow, and the promotion of various circular economic activities in colleges and universities is still limited and even ignored.

As an important symbol of social progress and stability, PA is an effective way to achieve sustainable universities by exerting the subjectivity and initiative of the implementer to actively participate in CE activities. In the sustainable university management model and organizational structure, the way and degree of participation of all relevant stakeholders will greatly affect the management effect. Public participation in the international association of public affairs and activities that are relevant to participation and empowerment in accordance with the degree of public participation, from weak to strong is divided into five grades (IAP2, 2007). The empowerment validity of public participation and its positive influence has also been proved by many scholars (Holyoak, 2001). It is also associated with the future of college students by enhancing their self-skills, such as self-motivation, self-confidence, and self-management, as well as other recognized competencies of openness (Harvey, 2000). Therefore, teachers, researchers, students, and logistics staff need to be mobilized and attracted to combine their work with CE activities. After all, no amount of abundant educational and scientific research assets in universities could improve CE performance if the implementer does not have an orientation towards CE. However, it is a limitation that PA’s effect is small on the implementer to consciously participate in promoting the various CE activities and may not guarantee a stable contribution to sustainable university construction.

The mix of PA and TDA combines the top-down administrative directives and bottom-up full participatory to guarantee the realization of SDGs by compensating for the defects of each mode when used alone. If EMS were implemented only through a top-down process, it might achieve environmental improvements in university operations, but it would exclude the educational aspects of campus sustainability. Only with the combination of adoption and participation, can EMS achieve all that it can achieve. Through an empirical survey of 47 universities with EMS across Europe, et al. found that in terms of EMS implementation methods, 21 universities are PA, 6 universities adopt TDA, and seven universities adopt a mix of TDA, except for 13 universities that are not applicable and have no data PA. The study demonstrates that EMAS was mainly implemented via a participatory approach, whereas ISO 14001 was implemented almost equally by a PA, TDA, and a mix of both approaches. ISO14001 implementation is more flexible. No matter what kind of EMS is adopted on campus, Hybrid management models and mechanisms are most effective in achieving the sustainable mission of the university, including reducing the institution's impact on the environment and conducting research and teaching (Disterheft et al., 2012).

In addition, in the campus management mechanism, quality management uses the inspection process of the Daiming circle, which needs to evaluate and inspect the management performance of colleges and universities. The traditional university ranking system is a performance evaluation of economic input-output, resulting in the lack of an internal driving force to carry out sustainable construction activities on campus. In order to promote the SD of colleges and universities, the new university ranking system should include the full input-output performance evaluation of environmental input (Lozano, 2011), as a fair value benchmark to measure sustainable campus construction.

There has been a research upsurge in the early 21st century, and the international academic circle has accumulated abundant achievements in the field of the sustainable campus evaluation system. Among these tools, the mature and representative ones are the National Wildlife Federation's State of the Campus Environment (NWF-SCE), University Leaders for a Sustainable Future's Sustainability Assessment Questionnaire (ULSF-SAQ), Auditing Instrument for Sustainability in Higher Education (AISHE), Campus Sustainability Assessment Review Project (CSARP), Penn State Indicators Report (PSIR) presented by Penn State Green Destiny Council of Pennsylvania State University, and Campus Sustainability Assessment Framework (CSAF). However, even mature and comprehensive evaluation tools still have some problems in practical application, such as difficulty in inter-institutional comparison, the excessive number of indicators, and inconvenient operation (Cole, 2003; Pipjelink, 2011).

Besides, UI GreenMetric World University Rankings (UIGWUR) launched by Universitas Indonesia and College Sustainability Report Card (CSRC) published by the American Sustainable Endowments Institute have been widely recognized as the authoritative assessment of universities' sustainability efforts. The main materials used as a basis for evaluation are mainly provided in the form of self-evaluation by the participating universities themselves and then reviewed by the organizers. The objectivity and accuracy of the evaluation materials cannot be guaranteed, see Table 1.9.

Table 1.9 - Sustainability assessment tools for higher education institution

Tools	Characteristic	Shortage
NWF-SCE	A qualitative research method is adopted to evaluate the performance of campus ecological work, which is comprehensive.	The respondents were mainly university presidents and staff of governing units.
ULSF-SAQ	It can be used to evaluate the functional interaction relationship of SD and to set targeted goals by finding weak links through exploring problems.	It cannot be quantified because there are no designed scoring criteria.
AISHE	The evaluation indexes are comprehensive and can be compared in different stages to facilitate the comparison between colleges and universities.	The whole evaluation system is complicated to understand
CSARP	It has the advantages of good comprehensiveness and a high degree of internationalization because university characteristics are considered indicators.	Due to the post-evaluation, there is a time lag and operability is insufficient.
PSIR	The evaluation index for the SD of green campus of a single university has outstanding superiority in evaluating the sustainability of a single campus.	It is not suitable for comparison of evaluation between universities.
CSAF	The two main systems for assessing campus sustainability are the human system and ecosystem system, which are both targeted and comprehensive.	Data acquisition in some universities is difficult and its operation is still not ideal
UIGWUR	It conducts an online survey and ranks the 912 participating universities in terms of their efforts at sustainability through 6 indicator categories.	The use of mainly university self-assessment tends to lack objectivity.
CSRC	It aims to grade the sustainability profiles of 322 universities in the United States and eight Canadian provinces with nine indicator categories.	Ranking activities have been suspended for 2012.
Green Degree	The target layer refers to the green degree G, and the five criteria layers are education, campus, scientific research, practice, and operation.	It is difficult to ensure the objectivity of the results through questionnaire survey.
GCES	It contains five indicator categories, and each category contains multiple sub-indicators	There are too many indicator items for easy operation.
GCCAP	The green campus assessment system is clearly explained to achieve at least 60% green campus requirements by 2022.	The specific evaluation standard of each city is not unified,

Source: prepared by the author based on official website data and information

In China, the evaluation index system of "green degree" is one of the commonly used evaluation systems for green universities (Chen & Zhang, 2003). Also, the evaluation standards of the Chinese government departments issued, such as the national standard GCES and the nationwide GCCAP, have the advantage of top-down channels to promote. However, it is difficult to ensure the objectivity of the results and is not convenient to operate in practice. In addition, domestic academic circles are lacking in the management of green campus software, especially the overall operation management, and there are few evaluation standards for the performance of campus management oriented towards CE.

International practice of sustainable university construction. As a special community with a large population, the university green campus project can provide conditions and environment to promote the realization of sustainable lifestyle for residents, and has been an important activity of sustainable education development in various countries. A lot of work has been done in the practice of green campus construction in the world. North America is represented by the United States and Canada, while Europe is represented by the United Kingdom.

American universities are more advanced than other countries in the practice of building green campuses. The SD of many universities has become a model for universities in other parts of the world. The green campus initiative on American campuses has been endorsed by national education authorities and has received guidance, standards acceptance, and certification from professional environmental bodies such as the USGBC. In addition, through sustainable education, campus greening construction, coordination, and cooperation of various environmental organizations and alliances, the stakeholders of green campus, such as administrators, teachers, students, staff, and enterprises, will be closely linked together to make the university have a broader influence. To support green schools, the USGBC established the Center for Green Schools in 2010. It is specialized in guiding and leading the green school construction movement in the United States to build all schools in the United States into green schools (Liu, 2014). At the same time, the green campus assessment system (LEED for Schools) based on Leadership in Energy & Environmental Design (LEED) was developed to test and assess the buildings of schools, with the highest LEED Gold-CI level (Platinum level).

In 1994, the Foundation for Environmental Education proposed a Europe-wide Green School Project, which has already become a worldwide project across Europe, Africa, South America, Asia, and Oceania. So far, the program has expanded to 59,000 schools in 68 countries. The program has expanded to effect change in some 59,000 schools in 68 countries across the Globe up to 2019. Since the 1990s, The UK began to advocate and spread the idea of "incorporating environmental protection into the daily management of schools" in higher education. In 1990, Britain published two research reports on furthering and promoting green action in higher education. From the practical action and curriculum to do two aspects. In 1992, higher education institutions focused on research and practice in solid waste and energy management, such as the University of Edinburgh, which established the Energy Environment Group to oversee energy management in schools. The University of Nottingham is keen on building a green campus, and the use of location selection, lighting, and energy-saving technologies has become a good example of a green campus.

Subsequently, in 1993, the British government established the Expert Committee on Green Environmental Education. The report Environmental Responsibility Agenda in Higher Education for first time described in detail the environment and SD in UK higher education institutions, as well as the outline of how to carry out relevant work in the future. After 1997, many universities in the UK jointly launched the Higher Education 21 Committee, which agreed on the SD strategy of universities. In particular, starting from the establishment of the environmental quality management system, the green campus actions, construction plans, and construction projects were incorporated into the quality system. Seek formal quality system certification to ensure the realization of the top goal of university SD. In the process of quality management, the Continuous Improvement of PDCA cycle is emphasized, and the whole process of SD of universities is guided by scientific methods. Table 1.10 shows some practical achievements of green campus construction worldwide.

Table 1.10 - Green campus construction practices in the world

Main body	**Countries**	**Practice or action**	**Organization or goals**
Harvard University	United States	Green Campus Action Plan	The Green Campus Committee was set up to take SD as the top-level strategic management goal of the university.
George Washington University	United States	green campus Initiative	The Office of Green Campus Programs is run by dedicated offices and administrative staff: academic research, facility construction and international exchanges.
University of California,	United States	Campus Environment planning	Adopt a natural and daily way of university management, and integrate the concept of green development into daily teaching.
University of Bulgary	United States	Campus Green Action	Willingness, efficiency, equity, cooperation, and natural systems, emphasize the public participation of academics, faculty, and staff.
USGBC	United States	Green School Centre	LEED brochure. It is the authoritative technical standard adopted by green building projects in the process of constructing green campuses in schools at all levels.
University of Waterloo	Canada	Green Campus Project	Unaffiliated with any organization or environmental declaration, the University of Waterloo proposes its five guiding principles for a green campus, emphasizing overall sustainability and participation by all faculty, students, and staff.
University of Edinburgh	Britain	Environmental agenda	Set up an "Energy and Environment Group" to lead the development of common energy management strategies.
University of Nottingham	Britain	Green Campus Construction	A series of sustainable innovations have been carried out on the site selection, planning, lighting, and ventilation of the campus.

Source: prepared by the author based on official website data and information

Tsinghua University is the first university in China to put forward the concept of green campuses. In 1985, Tsinghua University was approved to build the "green campus Demonstration Project". In 1999, Tsinghua University first proposed the construction of green campuses and established the green campus

Office. In 2001, The Environmental Protection Administration officially named Tsinghua University as the first green campus in China. The core content of its green campus construction includes green education, green scientific research, and green campus. Subsequently, Harbin Institute of Technology, Beijing Normal University, Guangzhou University, Tongji University, and other universities have also carried out the practice of green campus construction, and more universities have joined the ranks, see Table 1.11..

Table 1.11 - Green campus construction practices in China

Main body	**Region**	**Practice or action**	**Organization or goals**
Tsinghua university,	Beijing	Green campus initiative	green campus construction leading group has been set up with a green campus office, expert committee, and green technology consulting platform.
Harbin Institute of Technology	Harbin	Green project management	Various green projects have been composed to promote the awareness and concept of green environmental protection among teachers and students.
Shandong Jianzhu University	Jinan	Green building	Green technology and construction are adopted in to ensure the campus building is sustainable and strengthen the concept of green campuses.
Southwest Jiaotong University	Chengdu	Sewage resource recovery	A sewage reuse system is established in combination with small sewage treatment stations to achieve the best integration of economic benefit, environmental benefit, and social benefits.
Shantou university	Shantou	Reform of educational ideas	It aims to promote green management, green education, green technology, green service, and green environment.
Tiangong university	Tianjin	Green education	Green education curriculum system design research and demonstration have been implemented.
Huazhong Agricultural University	Wuhan	University green association	It mainly focuses on environmental education and field research to carry out various ecological protection and relevant publicity activities.

Source: prepared by the author based on official website data and information

To strengthen exchanges and cooperation among universities in different regions in the field of green campus construction, Tongji University, Zhejiang University, Tianjin University, and other 10 institutions jointly launched the China Green Campus Alliance, jointly leading and promoting the development of green campus construction in Chinese universities. At present, the number of members of the alliance has increased to 19, including Nanchang University, Tianjin University of Technology, Inner Mongolia Normal University, Xihua University, Ocean University of China, and Ningxia University. In 2011, Nanjing University also established the Alliance of Green Universities across the Taiwan Straits, and regularly discussed and communicated with universities in Hong Kong and Taiwan on the construction of green universities.

Both the GCES and GCCAP are considered as the top-down guidance document and evaluation basis and cover the construction of green campuses in primary and secondary schools, vocational colleges, and universities. However, up to now, the green schools at all levels are mainly primary and middle schools, while the process of establishing green universities is relatively slow. At present, although sustainable university construction has been carried out in China for several years, there are only a few universities that have constructed and implemented the working framework of sustainable university at the level of system management and strategy, and the construction of sustainable university is still at the initial stage. CE is a more specific and operable concept as a relative SD and is also an important means to achieve SD. Therefore, the construction of a CE-oriented asset management mode for universities can become an important approach to achieving the goal of sustainable university construction in China.

Conclusion to section 1

In section 1, this study focuses on the theoretical background of higher education institutions in promoting CE implementation. Universities are considered one of the primary driving forces in the CE transition, and the essence and value contributing to CE performance are analyzed comprehensively to verify this statement. A systematical literature review on the application and development of CE targets in the routine activities of universities is conducted to explore what has universities done in CE implementation. To introduce a practical foundation for the formation of a university CE activity management system, a comparative analysis of the management evolution, operation mechanism, and evaluation model of sustainable universities in the world is carried out. The main conclusions are as follows.

1. Through a systematic review of theoretical and practical explorations of CE models in China, it is summarized that the institutional design, technological progress, and pilot experience dissemination are the significant dependence for China to realize CE transition. Due to the lack of CE awareness and knowledge and the bottleneck of CE technology development, the way ahead of CE model promotion is still long compared to developed countries. It is determined that the university assets, including scientific research assets, educational assets, and campus operation assets, are closely related to these dependency factors.

2. By conducting a mixed analytical method of bibliometrics and qualitative content analysis, it is clarified that the main drivers of CE in China are government policy support, public participation, economic benefits, CE awareness and knowledge, and CE technological support, and the main barriers to CE are cultural barriers, market barriers, regulatory barriers, and technological barriers. It is identified that universities could exert an enormous influence on strengthening the drivers and eliminating barriers to CE through educational and scientific research activities, which implies that universities have bright prospects in speeding up the CE transition.

3. Through the connection analysis of the universities with CE implementation, it is highlighted that participating in the CE transition is a real need and inevitable choice for universities. Specifically, it is manifested in the following aspects, including the extensive initiatives of universities on the green campus, the provisions of relevant laws on the responsibilities of universities, the requirements for the functional evolution of universities, the need to inherit and develop the ecological civilization, and the needs of realizing scientific development of universities, as well as the potential on reducing corruption and unethical practices in universities.

4. It is generalized that the previous research on university CE activities is fragmented and disconnected from each other through the literature review, which mainly focuses on the construction and talent training model of CE-related majors, explicit and implicit curriculum design, instruction approaches and tools, and CE practice on campus. It is clarified that the lack of a comprehensive management system that can integrate these various isolated activities for an augmented effect has led to the emergence of this study.

5. It is summarized that the sustainable management practice of universities has experienced continuous progress and development from built environment certification to EMS and then to SMS. Either the green building initiatives or the sustainable management system comes up short when one is talking about a sustainable university because the functions of education, research, and community outreach are neglected. It is highlighted that establishing a more practical and down-to-earth CE management system in universities is essential compared to SMS.

It is generalized that the management system of CE-related university assets must be a two-way hybrid management model like sustainable universities, that is, a mixed management model of the top-down approach and participatory approach to guarantee the realization of SDGs. This raises the need for a clear implementable CE framework for universities, as well as active teachers and students with CE concepts and values.

SECTION 2: CONSTRUCTION AND EVALUATION OF CE-RELATED ASSET MANAGEMENT SYSTEM IN CHINESE UNIVERSITIES

2.1 Educational and scientific potential of Chinese universities in improving CE performance

CE embodies a new model of productivity development, so it requires corresponding productivity elements to match it, including laborers, labor materials, and labor objects, as well as science and technology, all of which need to be realized through education and scientific research. Therefore, CE education and technological innovation are important guarantees for CE implementation. However, the current popularity of CE education and the development level of science and technology in China is still unable to meet the needs of implementing a CE model. Universities have abundant educational and scientific assets, which have positive externalities to realize the CE transition in the whole society. Therefore, it is of great significance to explore the educational and scientific research potential of universities in the process of CE implementation.

Exploration of University educational potential in CE implementation. In recent years, all sectors of society are actively exploring effective ways of CE education. The Chinese National Development and Reform Commission and other four departments jointly issued the “Notice on the Regulations on the Declaration and Management of the National CE Education Demonstration Base”, focusing on building a high-quality CE education demonstration base as a platform to promote the CE concept to the public, and through the way of “replace subsidies with awards”, using the CE development special funds to support the national CE education demonstration base (PRC NDRC, 2013).

Hou (2017) took the education demonstration base of the Tianjin Ziya CE industrial zone as an example, analyzed the favorable conditions and main ways of establishing the education demonstration base of CE, as well as the restrictive factors in practice, and put forward feasible suggestions for Tianjin to develop CE education. Zhang et al. (2014) argued that public participation in CE education is the most effective and economic method in CE implementation, and proposed the path selection of public participation in CE education from the government, enterprises, communities, schools, and non-governmental organization level. As a driver to accelerate the CE implementation model, universities have the great educational potential for CE education and can provide reliable support for the popularization of CE education in the whole society.

- Subjects and objects of university CE education (UCEE). Before studying the UCEE, the subjects and objects of UCEE should be made clear first. In a narrow sense, CE education in colleges and universities is a kind of school education that incorporates CE knowledge into school education and teaching plans. The main subject of university education is the educator, that is, the teacher, and the object is the educated, that is, the student. In a broad sense, CE is an economy developed in a knowledge-based society. The concepts and values it advocates require the understanding, support, participation, and practice of the whole society. Therefore, CE education is a national, lifelong, participatory ability education (Yao, 2006).

As one of the main driving forces of promoting the CE model, the universities are not only the promoters of CE education at the whole society level, but also the cultivators of professional talents, the creators of advanced CE technology, and the pioneers and demonstrators of CE practice. Consequently, the subjects and objects of UCEE are more complicated. The main subjects of UCEE are not limited to teachers but should be extended to all departments and staff who participate in the CE practice in universities, such as the CE policy-making and planning department and the curriculum management department, and the graduates with knowledge and consciousness of CE who entered the society. These two groups are very large, but both are easily overlooked resources in higher education compared with teachers, which can be seen in Figure 2.1. Owing to the CE implementation depends on the whole society receiving a good education and a deep understanding of the CE concept, the objects of UCEE are no longer limited to college students, but the whole public.

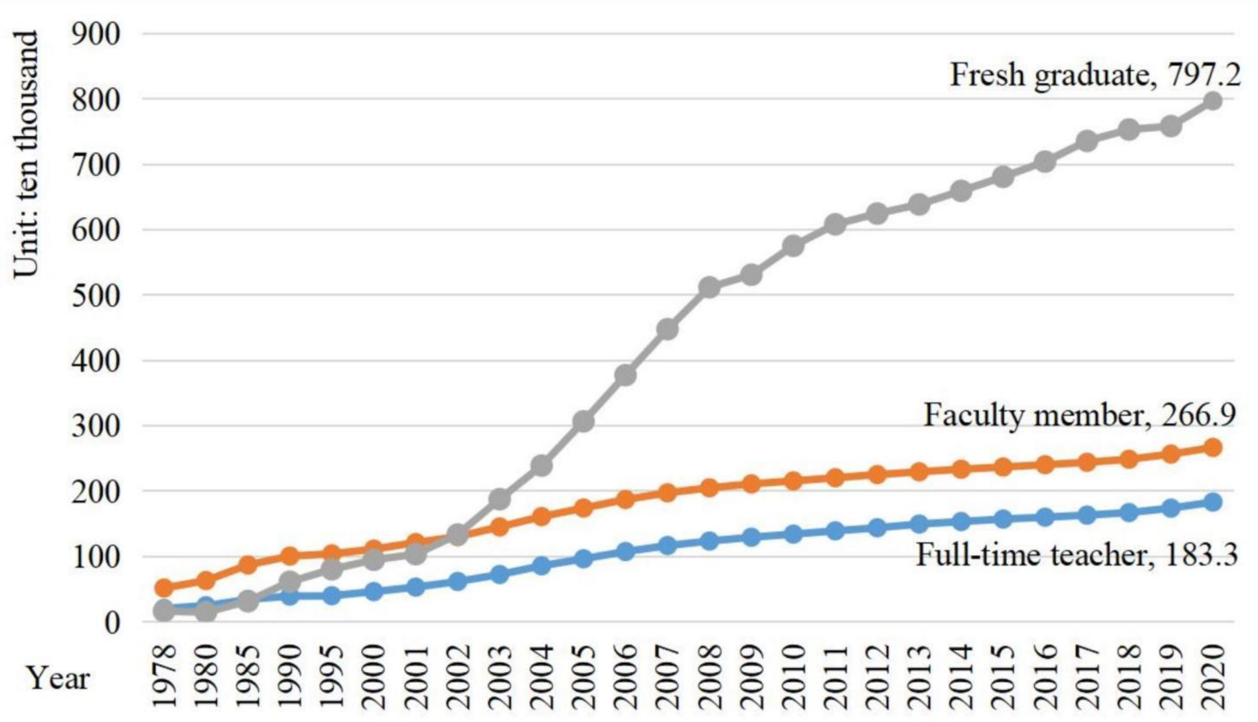

Figure 2.1 - Number of personnel in Chinese colleges and universities (2012-2020)

Source: prepared by the author based on the official website of PRC NBS (2020)

Through the analysis of existing research, it can be seen that the main subjects in universities to implement CE education include direct subjects (professional teachers with CE knowledge, the logistics staff with CE concept, and the students with CE knowledge) and indirect subjects (the CE policy-making and planning department, the curriculum management department, teaching faculties, and student social practice department), while the objects of CE education of universities mainly include students, residents of surrounding communities and the public, as shown in Figure 2.2.

In addition, the target of UCEE is not limited to the stage education of cultivating high-level professionals, but to the lifelong education of cultivating the whole social group as much as possible into citizens with CE concepts and knowledge. As for the educational mode, UCEE should not only carry out theoretical education but also carry out participatory practical education. Theoretical knowledge and intelligence should be put into innovative activities, and their ability should be properly displayed in CE practice to meet the needs of CE implementation.

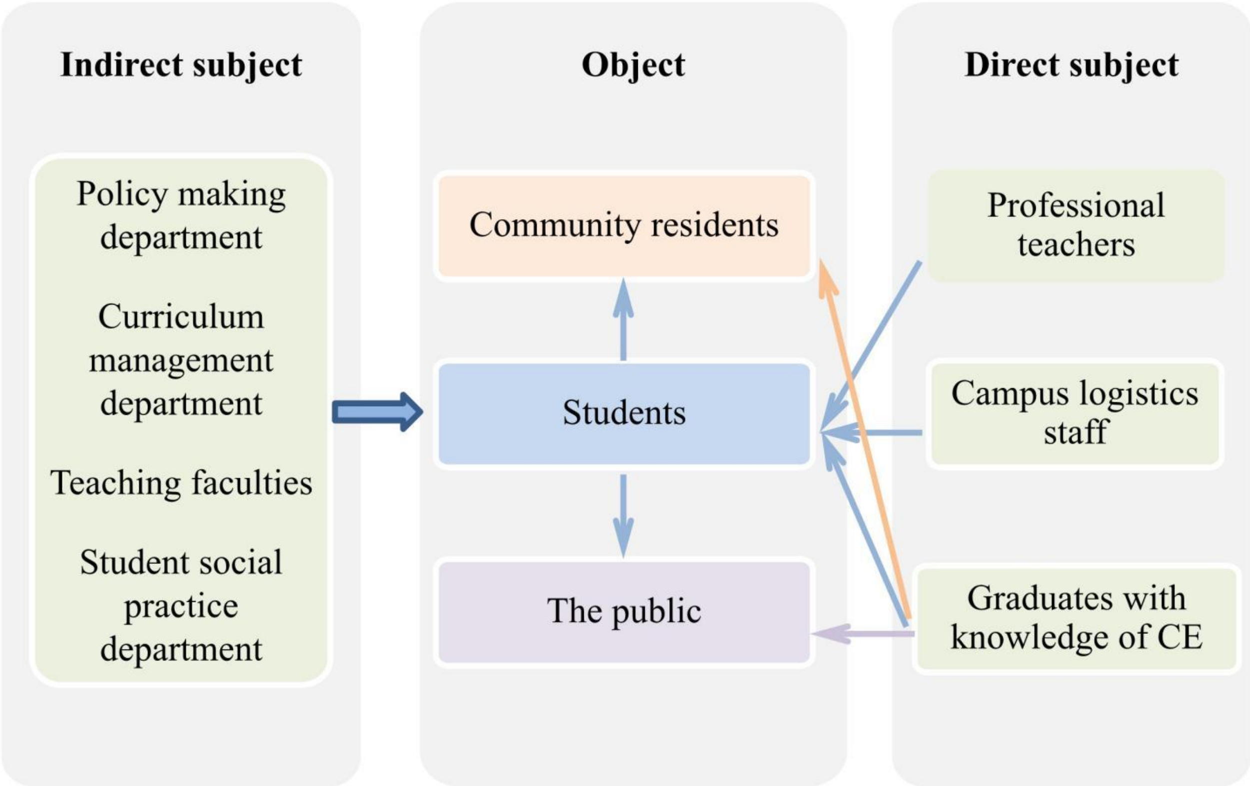

Figure 2.2 - Subjects and objects in implementing UCEE

Source: prepared by the author

Based on the above concepts, the definition of UCEE can be put forward for the first time. University CE education is a novel theoretical definition, which refers to a lifelong education with the guidance and support of relevant management departments of the universities, and the participation of all teachers and staff. It radiates education to the whole society with the education of college students as the core, aiming at realizing the two primary targets of cultivating high-level professional talents of CE and enhancing the awareness of CE of the whole public.

By analyzing previous relevant literature, this study found that although Chinese universities have explored CE education activities, the functions of university educational resources have not been fully exerted due to the existence of some barriers.

- **Specialty construction and curriculum setting.** As a new interdisciplinary major encouraged by our nation, RRSE involves the intersection and integration of environmental engineering, chemical engineering, and technology, applied chemistry, material engineering, machinery manufacturing and automation, electronic information engineering, management, and other disciplines. As CE implementation in China started later than that in developed countries, the professional development of RRSE also lags. Since the undergraduate major of Renewable Resources Science and Technology was established in 1996, more than 10 schools have applied for the program. In 2010, the Ministry of Education set up RRSE major and uniformly changed the original major into RRSE (Yao, 2006). The universities involved in the major name change include Yunnan Normal University, Beijing Jiaotong University Haibin College, and North China University of Water Resources and Electric Power, etc. The students of this major mainly study the recycling technology of waste resources, the remanufacturing of key mechanical parts, the performance and application of recycled materials, energy conservation and emission reduction benefit analysis, and other related scientific and technical issues of resource recycling.

Through the statistics carried out in early 2016, there are only 30 universities in China that had set up RRSE major, such as Peking University, Tsinghua University, and Nankai University (Cui et al., 2018). In this study, by consulting the list of newly-registered undergraduate majors published by the Ministry of Education each year from 2007 to 2018, it is found that before 2016, six other universities had set up the RRSE major, namely Hehai University, Anhui University of Technology, Jilin Institute of Chemical Technology, Henan Agricultural University, Yunnan Normal University, and Northwest Agriculture and Forestry University. Among them, Yunnan Normal University and Northwest Agriculture and Forestry University withdrew the major in 2016 and 2018 respectively. From 2016 to 2018, there are a total of 15 universities have added the RRSE major, which is increasing year by year. These universities are Zhejiang University, Shanxi University, a private university named Zhengzhou Institute of Industrial Technology, and others. There are also some colleges and universities applying for the program that have not been approved by the Ministry of Education, such as Leshan Normal College and Henan Institute of Science and Technology. By the end of 2019, there are 49 universities and colleges with RRSE, as shown in Table 2.1.

Table 2.1 - Universities that established RRSE major

University	Province /city	University	Province /city
Peking University	Beijing	Hunan University	Hunan
Tsinghua University	Beijing	Hunan Normal University	Hunan
Beijing University of Technology	Beijing	Fuzhou University	Fujian
Cangzhou Jiaotong College	Beijing	Fujian Normal University	Fujian
Shandong University	Shandong	Xi'an University of Architecture and Technology	Shanxi
Shandong Agricultural University	Shandong	Shangluo Institute	Shanxi
Shandong University of Science and Technology	Shandong	Changchun University of Technology	Jilin
Shandong Agricultural Engineering University	Shandong	Jilin University of Chemical Technology	Jilin
Dalian University of Technology	Liaoning	Qiqihar University	Heilongjiang
Northeastern University,	Liaoning	Northeast Petroleum University	Heilongjiang
Shenyang University of Technology	Liaoning	Kunming University of Science and Technology	Yunnan
Shenyang University of Chemical Technology	Liaoning	West Yunnan University of Applied Technology	Yunnan
Jiangsu Institute of Technology	Jiangsu	Anhui University of Science and Technology	Anhui
Hehai University	Jiangsu	Anhui University of Technology	Anhui
Nanjing Tech University	Jiangsu	Qinghai Normal University	Qinghai
Changzhou University	Jiangsu	Shanxi University	Shanxi
North China University of Water Resources and Electric Power	Henan	Neijiang Normal University	Sichuan
Henan Agricultural University	Henan	Zhejiang University,	Zhejiang
Zhengzhou Institute of Industrial Application Technology	Henan	East China University of Science and Technology	Shanghai
Luoyang Institute of Technology	Henan	Nanchang University,	Jiangxi
Wuhan Textile University	Hubei	Maotai Institute	Guizhou
Central South University for Nationalities	Hubei	Wuzhou Institute	Guangxi
Wuhan University of Engineering	Hubei	Foshan Institute of Science and Technology	Guangdong
Nankai University	Tianjin	Ningxia Institute of Technology	Ningxia
Tianjin University of Technology	Tianjin		

Source: prepared by the author based on official website data and information

Among all the provinces in China, Beijing, Shandong, Liaoning, Jiangsu, and Henan have the largest number of universities offering majors in RRSE. Also, there are still no universities offering this major in 7 provinces, such as Hebei and Chongqing.

According to the catalog of undergraduate majors newly released by the Ministry of Education, the major of RRSE is belong to the chemistry and pharmacy discipline. However, the faculty that RRSE major belonging is different because of the different advantages of disciplines and development targets in every university, for example, the Chemical Engineering faculty at East China University of Science and Technology, the Environmental Science and Engineering faculty at Nankai University, and the Materials and Manufacturing faculty in Beijing University of Technology.

These also reflect that there must be some differences in the focus of the professional curriculum in different universities. The RRSE major mainly adopts a combination of curriculum teaching and base training to train talents (Lv et al., 2017). Students in this major will mainly learn basic theoretical knowledge, and combine engineering training exercises to understand the basic conditions of China's resource distribution, industrial layout, and environmental protection so that they have the basic theoretical research and engineering ability to work in the fields of technology development and management.

By inducting the curriculum systems of various universities, it is found that the commonly used curriculum system is mainly composed of theoretical teaching parts, including general education courses, subject basic courses, professional core courses, and concentrated practical teaching, as shown in Table 2.2. However, the curriculum system construction overwhelmingly emphasizes the impartation of theoretical knowledge, while the curriculum setting has obvious defects in the cultivation of practical ability and vocational skills. Theoretical teaching is divorced from practical teaching, and the training of theoretical knowledge and practical skills are not coordinated, which leads to the poor practical ability of college students after graduation and makes it difficult to meet the needs of enterprises. For this emerging major, the universities that have offered this major are still in the initial exploration stage in terms of its construction ideas and curriculum system setting (Cui et al., 2018).

Table 2.2 - General curriculum system of RRSE major

Category	Target	Illustrate
General education courses	Basic skills and personal qualities	Foreign language, Legal basis, Computer, Mathematics, Chemistry, etc.
Discipline foundation courses	Basic knowledge and skills within the discipline	Chemistry, Materials, Recycling, Environment, Mining, and Metallurgy subjects.
Professional core courses	Professional core skills	Resource regeneration process and facility, Solid waste disposal, and recycling, etc.
Concentrated practical teaching	Ability to practice and innovate	Cognitive practice, Metalworking practice, Course practice, Production experiment, Graduation practice, Graduation design, etc.

Source: prepared by the author based on official website data and information

- Professional teaching staff and talent cultivation. The cultivation of recycling talents is the basis and guarantee of the development of the CE industry. Colleges and universities are the main sources for cultivating the talents of RRSE major and management talents that are urgently needed by society. In terms of the construction of the teaching team, there is no ready-made faculty for this major at the beginning of the establishment because the major of RRSE is a new discipline. Most colleges and universities formed interdisciplinary teaching and research teams across departments based on their respective strengths in related disciplines and further integration of the experts and scholars from the different faculties and other related fields, such as Nankai university. However, the insufficient number and the unreasonable structure make it difficult to improve the overall effectiveness of professional education. However, it is difficult to improve the overall efficiency of professional education due to the insufficient number and unreasonable structure of teaching staff.

In recent years, there is an average of about 1,200 students that graduated each year in the RRSE major (Liu et al., 2017). By reviewing the admissions plans issued by universities, this study statistics the enrollment of RRSE major in universities that clearly show data from 2017 to 2019, as shown in Table 2.3. It can be seen that the total enrollment of the RRSE major of the listed universities has not changed much in the three years. However, considering that the list in the table does not contain the universities that have added this major since 2017, the overall enrollment scale should increase year by year. However, it is important to note that the number of universities that withdraw the major may also change from year to year.

Table 2.3 - Admissions plans of RRSE major in some Chinese universities from 2017 to 2019

University	2017	2018	2019
Beijing University of Technology	38	19	0
Tianjin University of Technology	66	70	70
Changchun University of Technology	40	40	0
Anhui University of Technology	42	42	80
Fuzhou University	35	35	35
Shandong University of Science and Technology	40	40	0
Neijiang Normal University	35	30	40
Qinghai Normal University	40	40	0
Shangluo Institute	35	35	72
North China University of Water Resources and Electric Power	55	49	55
Shenyang University of Chemical Technology	30	60	60
Anhui University of Science and Technology	36	36	36
Total	492	496	448

Source: prepared by the author based on official website data and information

Graduates majoring in RRSE are employed in a wide range of employment fields, including R&D and management in metallurgical and chemical companies, R&D, and design of new technologies in scientific research institutes, production and management in enterprises using solid waste resources, management, and service work in the CE park, CE planning and consulting work in a specialized consulting agency, management and decision-making work in the government department. Taking Xi'an University of Architecture and Technology as an example, it can be generally understood that the main destination of graduates of this major is to participate in work and continue their studies to obtain higher degrees, as shown in Table 2.4.

Table 2.4 - Graduate destination of RRSE major from2015 to 2018

Graduate destination	2015	2016	2017	2018
Work	14	35	35	26
Postgraduate study	17	7	11	16
Enlist in the army	0	8	1	2
Go abroad	0	5	2	1
Freelance	1	1	0	2
Unemployed	2	1	3	0

Source: prepared by the author based on official website data and information

- General Education of CE. General education emphasizes all-around human development. The integration and development of general education and professional education can not only promote effective communication and exchange between different disciplines but also help to cultivate high-quality talents with both moral literacy and professional skills (Zhang, 2017). For non-CE major undergraduates, especially engineering students, conducting a CE general education course can not only help students integrate the concept of CE into the production practice of their specialty and then affect the CE concept in their professional field, but also can spread CE concept to the whole society through undergraduates' social practice activity and promote CE behavior in everyday life, such as green consumption.

At present, some universities have set up SD or environmental protection courses in the general education curriculum system, but few universities have incorporated CE courses into the system. On the one hand, some leaders and teachers of application-oriented colleges and universities think that general education is of limited practical significance, and they tend to focus on professional skills and are unwilling to put general education in the same important position as professional education. Its essence is still the insufficient understanding of general education or the supremacy of utilitarianism. On the other hand, some students pay little attention to general education. Due to the fierce competition in the current society, students always have a strong sense of pragmatism and attach more importance to professional courses. The general education class is treated worthlessly by the students because of the failure to recognize the importance of general education for personal growth and social development. In Table 2.5, the elective courses of general education offered by three universities are listed.

Table 2.5 - Elective courses of general education in universities

University	Optional courses in general education
Peking University	Mathematics and natural sciences, social sciences, philosophy and psychology, history, language, literature, art and aesthetic education, and social SD.
Zhejiang university	Literature and art, history and culture, society and economy, leadership and communication, technology and design.
East China University of Science and Technology	Humanities, social sciences, engineering, natural sciences, and innovation and entrepreneurship.

Source: prepared by the author based on official website data and information

- Overlooked hidden curriculum of CE. As an important way of higher education, classroom teaching pays attention to the transfer of knowledge and the cultivation of cognitive ability. Classroom teaching belongs to explicit education, which should not be the whole of higher education. Higher education should be an open and continuous process of educational activities, rather than merely imparting knowledge in a fixed place (classroom) according to a fixed textbook. The higher education students receive should be holistic, that is, the integration of intellectuality, rationality, and emotion (Gao and Bai, 2021). If colleges and universities only focus on explicit courses, they will ignore educational factors hidden behind knowledge and life scenes, namely implicit education, resulting in low educational effectiveness.

The concept of the hidden curriculum was first coined by American scholar Philip Jackson (1968) in his book “Life in Classroom”, in which he proposed that many other non-obvious school characteristics other than explicit curriculum formed a unique cultural atmosphere and thus constituted the hidden curriculum. As an important supplement to explicit education, the concept of implicit education is developed from the implicit curriculum, which is usually regarded as an unconscious education mode that the educatees are not aware of psychologically. The recessive education in colleges and universities is to infiltrate the educational content into the university environment, culture, entertainment, public opinion, service, system, management, and other daily campus life atmosphere, through a subtle way to make college students accept the pre-set educational content or have some positive or positive impact on college students. Colleges and universities should not only teach open courses but also indirectly convey values and value orientation to students through hidden factors such as school culture, which is very helpful for them to enter society in the future (Dreeben, 1967).

However, the recessive education of CE in colleges and universities has been neglected or abandoned. For example, the school’s logistics department is well-equipped to organize and implement campus CE practices, such as kitchen waste recycling projects. At the same time, logistics work is closely related to student's life and has the direct advantage of recessive education of CE. However, the current Chinese university administrators have a single position in the logistics department, which mainly requires it to do a good job in all aspects of logistics support, indirectly serving the teaching and scientific research of universities. Through consulting the relevant data of all 134 colleges and universities in Henan Province of China, it is found that there is not a single college that has made relevant support policies for logistics departments to organize CE practice or provided support for logistics departments to directly participate in CE implicit education through policy level.

- CE education radiation to surrounding communities. The CE education radiation of the extracurricular activities of student associations and the social practice activities to the public is not enough. At present, many universities have set up Environmental Protection Associations to spread the concept or knowledge of CE among students. The student social practice department in universities also regularly organizes students to participate in environmental protection training and competition based on their major, which to some extent makes up for students' lack of knowledge in this field. However, there are still few pro-circular activities between colleges and communities, and the effect of the CE educational radiation from universities to the whole society is still not significant.

Strategies for developing the potential of UCEE. The potential of CE education in colleges and universities is mainly reflected in the following aspects.

- Promotion of specialty development and talent cultivation. The development of RRSE major is relatively lagging behind developed countries, and it is necessary to attach importance to specialty construction to lay a solid foundation for promoting the CE transition. Obviously, if a university does not offer RRSE major, it will not hire professional teachers in this major, and it is very unlikely to train CE professionals and undergraduates with CE concepts and knowledge. That is to say, there are only a limited number of universities in China offering relevant majors in CE, so the educational activities directed by lecturers towards CE cannot be implemented smoothly in all colleges and universities.

The CE-related specialty is an emerging specialty in China, its development is still in the initial stage, and there is great space for further development. Colleges and universities should promote professional development and talent training according to the needs of the society for professionals in CE, which is the guarantee for the development of CE and the resource recycling industry. On the one hand, engineering universities that have not yet established the RRSE major, including mining and metallurgical universities, metallurgical universities, chemical universities, and materials universities, should all apply to add CE majors based on the development of traditional specialty disciplines, improve its discipline group, promote the development of specialty disciplines to cross disciplines and marginal disciplines, and actively implement the national strategy of strengthening the country with human resources in CE. On the other hand, colleges and universities that have established this CE major should scientifically target the training of talents based on their actual situation and social needs, firmly grasp the direction of service development and promote employment, deepen the reform of institutional mechanisms, innovate education models, adhere to the talent training model of integration of production and education and cooperation between schools and enterprises, and actively cultivate qualified application-oriented talents that meet the needs of green development.

- **Improvement of the curriculum setting.** The curriculum system is composed of courses set by the major according to the arrangement and combination of teaching content and process, which is a relatively complex and dynamic state and is the core of professional talent training, whose rationality determines the quality of the professional talent training (Liu et al., 2017). It is necessary to optimize the curriculum system of the CE specialty to meet the needs of developing CE teaching. The administrative departments of education should carry out CE research of specialty construction in a planned and organized way, formulate scientific and reasonable training programs, and establish a guarantee system of talent training to strengthen the training of talents in the field of CE.

Universities should strengthen the idea of serving local areas and build a special curriculum system oriented to industry needs. Firstly, it is necessary to adhere to the basic principles of broadening the foundation and increasing the practical teaching links to carry out the reform of course teaching content. It is also necessary to comprehensively consider the knowledge requirements involved in this specialty and tightly focus on the circular development goals to establish the professional curriculum in the following fields, including chemical, materials, comprehensive utilization technology, mineral and metallurgical extraction technology, and environmental protection. The distinctive curriculum system and professional direction should be built in accordance with the needs of the local industry (Cui et al., 2008). Secondly, teaching activities should be combined with production practice. Enterprise technicians could be invited to participate in the compilation, teaching organization, teaching and assessment of teaching syllabus, and compiling textbooks for major courses with engineering application as the background, so that students' theoretical learning and practical production are closely combined. Furthermore, it is necessary to innovate curriculum assessment methods. Professional employment requires relatively higher practical ability. Therefore, credits should be focused on practical teaching in the assessment of the curriculum. It is also recommended to increase the content of practice in the assessment of the theoretical curriculum to guide students to strengthen the cultivation of practical operation and innovative ability.

- **Enhancement of education function of the hidden curriculum.** The influence of implicit courses in CE education cannot also be ignored. With the support of relevant government policies, universities can carry out lots of CE practices, which will become an important way for universities to conduct CE education and publicize the CE concept. Actually, many foreign universities have started different practices of CE. In China, although the role of universities in promoting the transition to the CE model has been widely recognized, and the work of energy conservation and environmental protection in universities is evaluated by higher education authorities every year, similar practices are still rare in Chinese colleges and universities.

If universities integrate the CE into their development programs and formulate relevant development policies, the logistics department can combine the advantages of the university to actively explore the CE practice in various fields of the university. Pilot projects in universities could be arisen to catalyze the CE practice by working with businesses to improve eco-effectiveness as well as eco-efficiency, see Figure 2.3. For example, universities can establish the campus domestic waste sorting system, the reclaimed water circulation system, the shared cycling system, the learning resources recycling system, and the canteen waste recovery system. Whether water recycling or food recycling on campus, these are kinds of hidden extra-curricular education in daily life. Moreover, logistics staff with the CE concept can play an active role in the process of non-classroom environmental education, and its influence on students' pro-circular behaviors can be as effective as formal CE education. The implementation of extracurricular education of CE in universities relied on the CE practice on campus and the logistics staff, as shown in.

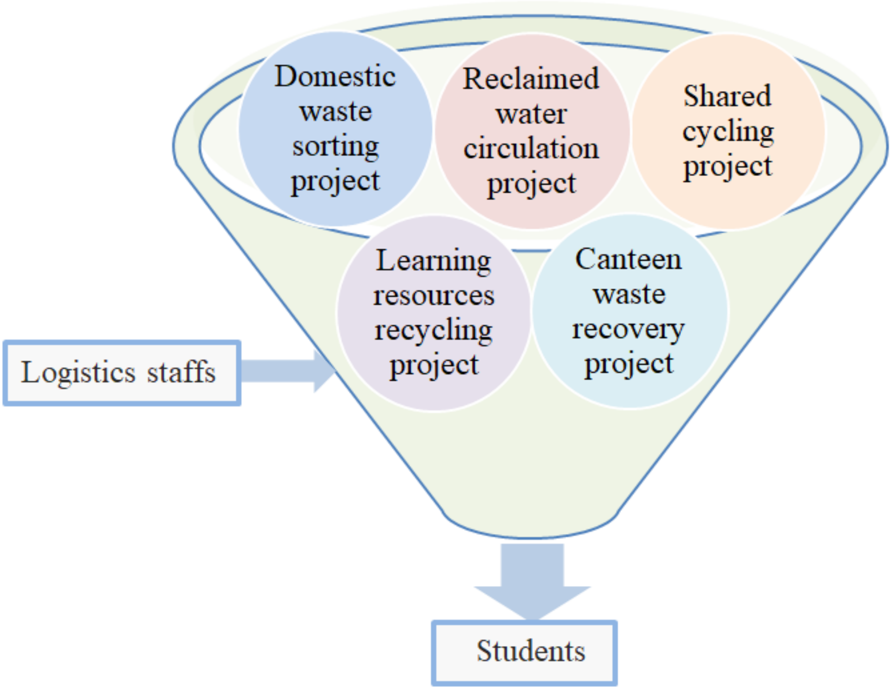

Figure 2.3 - Implementation of extracurricular education of CE for students

Source: prepared by the author

- Enrichment of general education of CE. The elective courses related to CE need to be further enriched to enhance the CE awareness and knowledge of undergraduates. National Bureau of Statistics of China shows that the number of university graduates in China has exceeded 7 million every year since 2013 (PRC NBS, 2018), that is to say, university students are a so huge group that could become disseminators of the concept of CE after graduation, improve the CE awareness in the whole society, and promote the CE implementation. There is great significance for the personal growth of undergraduates and social development to list the general education course of CE as the content of general education of all majors in universities (Chen, 2019).

The teaching management department of colleges and universities should strengthen the overall arrangement of general education on CE. The first is to raise awareness of the importance of general education in CE, and establish a specialized general course management organization and assessment mechanism to ensure the sound development of general education. Secondly, the CE general education curriculum should be established scientifically. Universities should strengthen the scientific justification of the courses to be offered, rationally set course modules, carefully arrange course content, scientifically organize, and implement course teaching, so as to integrate general education and professional education to complete the goal of general education of CE. The third is to pay attention to the development of online course resources to ensure the needs of CE teaching. At present, especially in universities that have not established a CE major, professional teachers are scarce. Colleges and universities should improve the integration of teachers in the region, and carry out general education on CE through a combination of full-time and part-time teachers and online and offline teaching.

- Construction of teacher team of CE-related majors. There is a shortage of teachers in RRSE major, so it is necessary to create a talent pool of high-quality teachers to ensure the quality of talent cultivation. Strong professional construction is closely related to high-level teachers. Strengthening the dominant position of teachers in university education and focusing on the establishment of a high-quality, high-level team of subject-professional teachers is the top priority of the current new professional construction (Liu et al., 2017).

Firstly, it is necessary to increase efforts to introduce talents in this field, formulate various preferential conditions to recruit high-level talents, especially to introduce discipline leaders and backbone teachers of main courses urgently needed in the construction of the new major, further optimize the faculty structure, and create good internal conditions for the establishment of the new major. The second is to attach importance to the training of existing talents, give full play to the guiding role of old teachers, promote the development of young teachers, support teachers to study and visit, and improve the level of the whole teaching staff. Additionally, to optimize the employment structure of teachers, relevant high-level professionals can be hired as part-time teachers in the new profession, to achieve a reasonable allocation of social education resources, and gradually build a high-quality teacher team with a reasonable structure and great potential for development, to help the establishment of new professions good foundation. Furthermore, the construction of a "double-skilled" teacher team could be improved, for insurance, paying attention to the training of dual-skilled talents, arranging for teachers to regularly conduct production practice in enterprises, and hiring enterprise technical staff to teach and exchange.

- Extension of the influence and scope of education radiation. In terms of educational radiation to society, the student social practice department and propaganda department of universities should improve the cooperation with surrounding communities and other relevant institutions in society. With the educational resources, universities can integrate CE knowledge and concepts into social practice, spread the pro-circular value to surrounding communities and the public, and guide residents to form green consumption habits. For example, Japan is a country that suffered from heavy environmental disasters, so they build many environmental education sites with excellent practical functions, aiming to promote public awareness of the environment and form spontaneous pro-environment behaviors (Lin & Shi, 2013).

In China with the educational resources and the platform of student social practice, universities can use for reference the successful experience of environmental education venues in Japan to set up CE education venues in conjunction with the community to provide visiting and explanation services for community residents and primary and secondary school students and collect volunteers to carry out online and offline publicity and education in various forms. By adopting flexible and intuitive ways, public participation can be enhanced. Also, the effect of CE education can be improved by continuous improvement of educational methods through obtaining feedback.

Analysis of university scientific potential in CE implementation. In the context of China’s transition of development mode and upgrading of industrial structure, the Chinese government also attaches great importance to the important role of innovation-driven development in SD and requires the implementation of the strategy of "innovation-driven, endogenous growth, structural adjustment, and green development". Universities should not only play the role of talent cultivation and education but also play an important role in technological innovation and knowledge innovation as one of the main bodies of the regional innovation system, such as the output of green scientific research and services and the collaborative innovation and development of the industry-university-research institute. Modern universities, especially research universities, have become as important a social structure as enterprises and governments. It is realized that regional innovation has entered the "university-industry-government" three-helix innovation mode (Etzkowitz et al., 2007). Moreover, in the process of knowledge production, transfer and spillover, universities have positive externalities for regional innovation and economic and social development.

In practice, the university's science and technology and social services can have a rapid and lasting impact on CE implementation, which is different from professional talent cultivation and the lag that affects the process. Moreover, considering the influence of tacit knowledge spillover, the contribution of universities to the whole social innovation is greater than the explicit contribution of patents and scientific and technological achievements transition in the current industry-university-research collaborative innovation. Therefore, from the perspective of innovation economics, this study tries to explore the potential impact of the dissemination, application, and transition of university science and technology on sustainable economic and social development, especially the knowledge spillover effect of Chinese university research output on enterprise technological innovation.

- Research on knowledge innovation and spillover in universities. Knowledge innovation refers to the process of acquiring new basic and technological scientific knowledge through scientific research, including basic research and applied research. As for university knowledge innovation, some researchers believe that it is a process of material exchange (Wu et al., 2008), and regard the knowledge transferred from universities to enterprises through cooperation and technological transition as the achievements of university knowledge innovation. Subsequently, the scope of knowledge innovation in universities is constantly expanded, covering the whole process from the creation of scientific and technological knowledge to the realization of knowledge value. For example, scientific and technological papers and patent applications are regarded as original knowledge innovation, while patent authorization and technology transfer are regarded as the application and commercialization of knowledge. In fact, from the perspective of knowledge externality, university knowledge innovation should include explicit knowledge innovation and invisible knowledge innovation. The contribution of universities to the innovation of the whole society is greater than that of patents and the transition of scientific and technological achievements in the current industry-university-research collaborative innovation.

As for explicit knowledge innovation in universities, according to the Compilation of Statistics on Science and Technology in Universities, the main explicit output of knowledge innovation in universities from 2016 to 2020 is listed in Table 2.6.

Table 2.6 - Main explicit output of scientific innovation in universities

Year	2016	2017	2018	2019	2020
Number of science and technology works	13,113	14,046	13,824	14,685	13,619
Number of scientific papers published	870,529	918,161	957,341	1,026,200	1,083,321
Number of scientific papers published in international journals	302,414	343,999	376,836	444,735	523,834
Number of state-level projects accepted	4,884	4,628	3,359	3,214	2,743
Number of patent applications	184,423	229,458	266,418	310,276	330,375
Number of patents granted	121,981	144,375	163,157	184,934	206,036
The total amount of patent sales (thousand China Yuan)	2,774,739	2,269,711	2,931,998	3,390,858	4,039,648

Source: prepared by the author based on official website data and information

The indicators involved include the number of published scientific and technological works, the number of published scientific and technological papers, the number of published papers in foreign journals, the number of national and project acceptance, the number of patent applications, the number of patent grants, the total sum of patent sales/income, etc.

The influence of tacit knowledge innovation in universities usually involves the concept of knowledge space. According to the knowledge space theory, universities and research institutions with a certain scale and level in a region are engaged in knowledge production. When the accumulated knowledge reaches a certain critical value, it will overflow and be transformed into real productivity to realize the capitalization of knowledge. Existing research results show that in the same large economic circle and the local region, the knowledge spillover effect of university innovation is very obvious, and also has a spillover effect on the surrounding area (Anselin et al., 1997).

In addition to being measured in terms of patent and publishing activities, proximity to a university and a firm is more likely to communicate with each other, enhancing the learning effect of the firm on innovation (Anders, 2010). Some researchers also believe that regional competitiveness and university knowledge spillover effect affect enterprises' innovation behavior, and the existence of research universities in a region will make enterprises in the region more innovative and competitive (Audretsch et al., 2012).

It is difficult to measure the externality of university knowledge innovation by a certain index. Based on the empirical analysis of foreign countries, this study considers that university knowledge innovation outputs have spatial spillover effects on enterprise innovation activities. Through spatial econometric analysis, this study empirically explores the spatial correlation between university knowledge innovation output and regional and provincial innovation indicators.

- Dimension reduction method based on factor analysis. Exploratory factor analysis in SPSS23.0 was used to explore that the analysis items should be divided into several factors (variables), and the weight of each factor and the composite score of the factors were calculated using the rotated variance interpretation rate value for further analysis. During factor analysis, the results of the KMO test and Bartlett sphericity test should be used to determine whether the selected data is suitable for factor analysis. Then, based on judging the corresponding relationship between factors and items, several analysis items are condensed into a few factors, and the factors are named.

In the process of factor analysis, the factor load is estimated by selecting the type of factor load matrix, and the factor score of the evaluation unit is calculated according to the common factor with the strong explanatory ability and the contribution degree of the factor to the total variance. In addition, the weight of each factor can be obtained by normalization, that is, dividing the variance interpretation rate of each factor after rotation by the cumulative variance interpretation rate after rotation. The factor synthesis score is calculated by summing (factor score * variance interpretation rate after rotation)/ cumulative variance interpretation rate. The variance contribution rate of each factor was taken as the weight, and each factor was weighted and summed, for example,

$$Fx=0.445F1+0.307F2+0.152F3+0.096F4 \tag{2.1}$$

- Spatial correlation test. Moran's I and Gearys' C are commonly used to test the spatial correlation of innovation. The spatial autocorrelation index Moran's I is suitable for global spatial analysis, and its calculation formula is as follows:

$$Morans'I = \frac{n}{S_0}\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}W_{i,j}Z_iZ_j}{\sum_{i=1}^{n}Z_i^2} \tag{2.2}$$

Where, n is the total number of regions (n=31 in this study), and $W_{i,j}$ is the spatial weight between region i and region j, and represents the mutual adjacency relationship between factors defined by adjacency standard or distance standard in space objects, Z_i represents the attributes of region i and their average value ($X_i - \bar{X}$). $\bar{S}_0$ is the aggregation of all spatial weights, namely

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n}W_{i,j} \tag{2.3}$$

When Moran's I is greater than 0, it indicates that the data presents a spatial positive correlation, and the larger the value is, the more obvious the spatial correlation is. When Moran's I is less than 0, it means that the data presents a spatial negative correlation, and the smaller the value is, the greater the spatial difference is. When Moran's I is 0, the space is stochastic. When interpreting the calculation results of Moran's I, P values and Z scores are also needed to test the significance level of spatial autocorrelation. P values that less than 0.05 (passing the 95% confidence test) and Z scores that more than the critical value of 1.65 (the threshold set by rejecting the null hypothesis) indicate a positive correlation. If the Z score is negative and passes the significance test, there is a negative correlation.

The global spatial autocorrelation index only indicates the overall distribution and correlation degree of a certain social and economic phenomenon in the research area. In order to explain the spatial distribution of clusters with similar attributes, further local spatial autocorrelation clustering analysis is needed, and the results mainly show four manifestations, including high cluster (HH), low and low cluster (LL), low and high cluster (LH) and high and low cluster (HL).

- Index selection and data sources. According to the actual situation, this study selected the sample data of 31 provinces, municipalities, and autonomous regions in China from 2016 to 2020 for statistics. For the output index of knowledge innovation of universities, indicators are mainly selected according to the achievements of knowledge innovation of universities, including the number of published scientific and technological works, the number of published scientific and technological papers, the number of patent applications, and other items during 2016-2020. The above items are represented by the average value of the five years. For regional innovation indicators, this study selected the number of patent applications of different provinces, the number of patent applications of industrial enterprises above medium and large size, and sales revenue of new products, and also adopted the average value of these five years.

All data are from China Science and Technology Statistical Yearbook 2017-2021 and University Science and Technology Statistical Data Compilation 2016-2020.

- Factor analysis. First, the dimension of the knowledge innovation output index is reduced by factor analysis. Because of the processing of variables, R-type factor analysis is used. In order to verify the applicability of factor analysis, this study uses SPSS23.0 software to conduct the KMO test and Bartlett test on the relevant data of 7 projects involved in the output index of knowledge innovation in colleges and universities.

As shown in Table 2.7, the KMO test value of 0.763 is greater than 0.7, which means that the data can be used for factor analysis research. The data passed the Bartlett sphericity test ($P < 0.01$), indicating that the study data were suitable for factor analysis.

Table 2.7 - Results of reliability and validity tests

KMO value □		0.763
Bartlett sphericity test	Approximately chi-squared □	354.726
	df	21
	P values	0.000 * *

Note: * $p < 0.05$, ** $p < 0.01$

Source: prepared by the author

SPSS23.0 was used for factor analysis of 7 items, and it was found that the system automatically extracted one factor through concentration processing, with a characteristic root value of 5.629 (>1), and the explanation rate of factor accumulative variance was 80.411%. The data in this study were rotated using the maximum variance rotation method (VARImax) to find the corresponding relationship between factors and study items. The results showed that the factor loading coefficient and common degree values of all the research items were higher than 0.4, which meant that there was a strong correlation between the research items and the factors, and the factors could effectively extract information. The "component score coefficient matrix" is used to establish the relationship between the factors and the study items. According to the proportion of their contribution to each other, the weight is allocated, and the score of the comprehensive output factor of knowledge innovation is calculated as the output index.

- Spatial correlation analysis. The global autocorrelation analysis is made on the number of university patent applications and the comprehensive output of university knowledge innovation in 31 provinces of China from 2016 to 2020, and the global economic spatial correlation analysis is made on the number of patent applications of corresponding provinces, the number of patent applications of industrial enterprises above medium and large size and the sales revenue of new products. The univariate Moran’s I analysis results show that the number of university patent applications and the comprehensive output of university knowledge innovation show strong spatial autocorrelation, indicating that university knowledge innovation has an impact on the knowledge innovation of neighboring universities in both theoretical research and application transition stage, see Table 2.8.

Table 2.8 - Univariate global Moran’s I and test statistics of university R&D output

University R&D output indicators	Moran’s I	P	Z
Number of university patent applications	0.143	0.049 *	1.6854
Comprehensive output of university knowledge innovation	0.198	0.04 *	1.9715

Note: * $p < 0.05$, ** $p < 0.01$

Source: prepared by the author

In addition, Moran’s I analysis of university R&D output index and provincial innovation indicators shows that the spatial correlation between university patent application and patent application of corresponding provinces and enterprises is relatively weak, indicating that there is a certain degree of competition between the two. The spatial correlation between the comprehensive output of university knowledge innovation and the provincial innovation indicators is relatively stronger, indicating that the comprehensive output of university knowledge innovation has a greater impact on the innovation activities of enterprises in the neighboring region, see Table 2.9.

Table 2.9 - Bivariate global Moran's I and test statistics of university R&D output and provincial innovation indicators

University R&D output indicators (the first variable)	Provincial innovation indicators (the second variable)	Moran's I	P	Z
Number of university patent applications	Number of patent applications	0.01	0.404	0.1593
	Number of patent applications by large and medium-sized enterprises	0.060	0.362	0.381
	Revenue from new product sales	0.043	0.222	0.6948
Comprehensive output of university knowledge innovation	Number of patent applications	0.206	0.017*	2.3238
	Number of patent applications by large and medium-sized enterprises	0.179	0.027*	2.0972
	Revenue from new product sales	0.254	0.009**	2.8744

Note: * $p < 0.05$, ** $p < 0.01$

Source: prepared by the author

In particular, the spatial correlation between the comprehensive output of university knowledge innovation and the sales revenue of new products is the strongest, indicating that the comprehensive output of university knowledge innovation is closely related to the innovation and management of enterprises.

Further, bivariate local Moran's I analysis (LISA) was conducted to explore the spatial correlation between the comprehensive output of university knowledge innovation and the sales revenue of new products in the province at the significance level of 5%. The analysis results show that the Yangtze River Delta region (including Shanghai, Jiangsu, Anhui, Zhejiang, and other provinces) has a high positive correlation, while Inner Mongolia, Yunnan, and western provinces have a low positive correlation to the surrounding areas, see Table 2.10. According to the measurement model of regional knowledge spillovers proposed by Max et al., technology distance, knowledge gap, and learning ability are the basic factors affecting regional knowledge spillovers. The Yangtze River Delta region has relative advantages in the regional economy and competitiveness level, university resources, technological and cultural level, industrial cluster, and hierarchy distribution, and has a strong knowledge spillover effect, see Figure 2.4.

Table 2.10 - Spatial correlation patterns of the comprehensive output of university knowledge innovation and sales revenue of provincial new products

Quadrant	Patterns	Provinces and autonomous regions	Amount
The first quadrant	High-High	Shanghai, Jiangsu, Anhui, Zhejiang, Shandong	5
The second quadrant	Low-High	Jiangxi, Fujian	2
The third quadrant	Low-Low	Inner Mongolia, Ningxia, Gansu, Xinjiang, Tibet, Qinghai, Yunnan	7
The fourth quadrant	High-Low	Sichuan	1

Source: prepared by the author

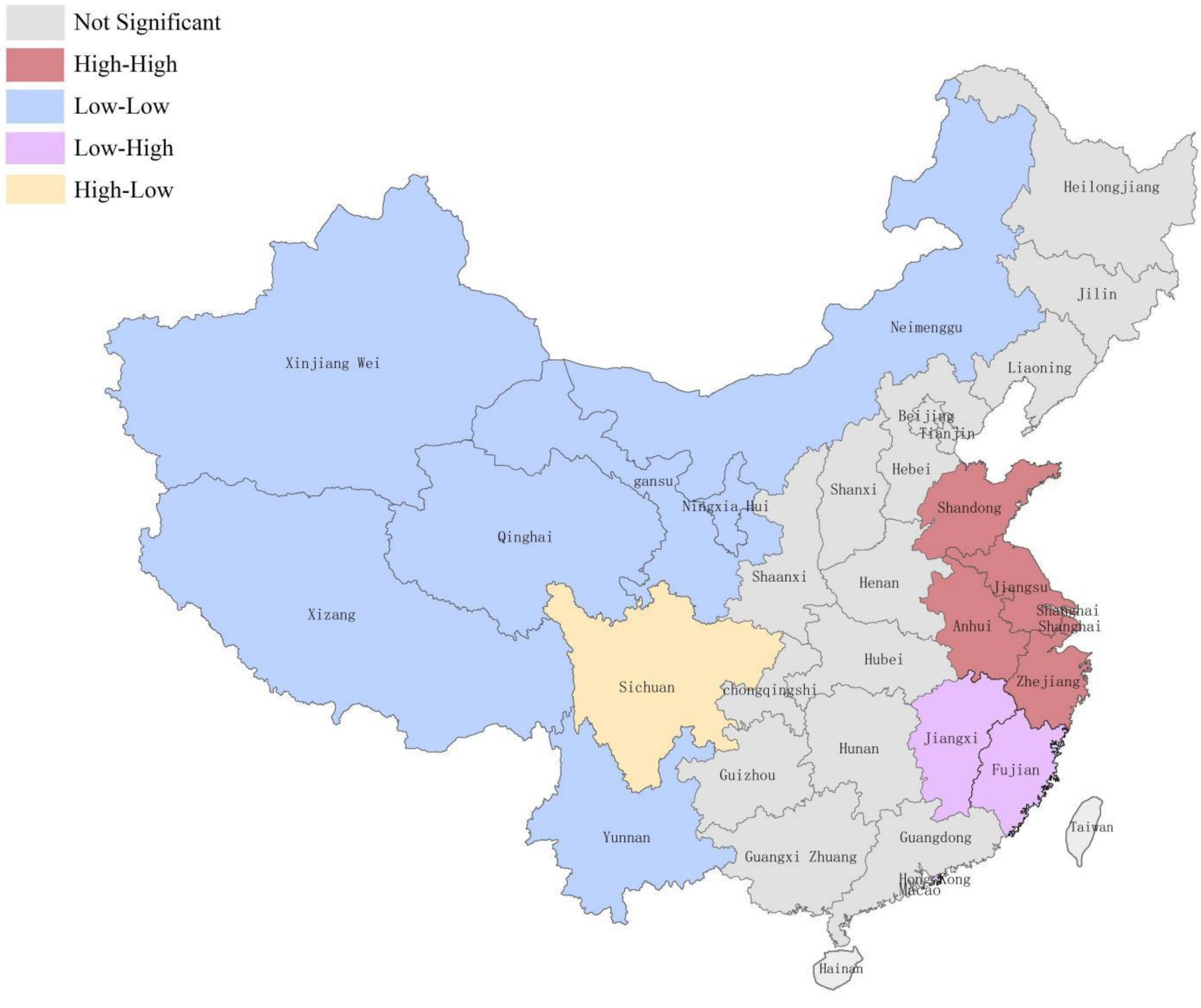

Figure 2.4 - LISA cluster map of comprehensive output of university knowledge innovation and sales revenue of provincial new products

Source: prepared by the author

Suggestions for improving the scientific potential of universities. There is a strong spatial correlation and dependence between university knowledge innovation output and provincial enterprise innovation indicators, and the local correlation is most obvious in the Yangtze River Delta region. Therefore, the impact of university CE knowledge output on enterprise CE innovation includes at least four aspects: CE graduate output, CE research activities and technology transfer, industry-university-research cooperation, and CE knowledge sharing. However, at present, university knowledge and technological innovation have promoted effect and regional spatial correlation on enterprise technological innovation, but also have adverse factors such as indirect effect, complex form, and low technology conversion rate. In reality, the basic research led by universities and scientific research institutes in China is still not fully connected with the applied research and development of enterprises. Therefore, the potential of scientific and technological innovation in colleges and universities should be brought into full play to contribute to the advancement of social CE technology.

First, colleges and universities can further improve the existing CE training, research mechanism, and information platform construction, and improve the functions of universities as public service departments, so that innovation and knowledge have more externalities. Universities have three functions cultivating talents, innovation, and social service, and are closely related to enterprise innovation and regional innovation. The stock level of human capital has an indirect impact on regional innovation output and spatial correlation, while science and technology and knowledge sharing can directly promote firm innovation.

Second, the government should form an effective management system to make the direction of CE research and resource allocation more scientific. Under the traditional system, the promotion efficiency of university scientific and technological achievements and knowledge innovation to the industry is low. In recent years, enterprises and universities began to jointly apply for science and technology projects, reflecting the trend of industrialization of scientific research. Some scholars believe that enterprises should put forward demands and bids, universities and research institutes should obtain them through bidding, and the government should provide subsidies or policy support according to the project situation (Liu et al., 2011). The connection and distribution ratio of general basic research, industry-driven basic research, and industry-applied research needs to be further optimized.

Third, the government should establish clear rights and responsibilities and benefit distribution mechanisms for the cooperation and commercial relationship between universities and enterprises. In the contact between enterprises and universities, knowledge spillover occurs through the flow and exchange of personnel and technology or the direct transfer of technological achievements. However, the research and development of enterprises are closer to the end of the product and they can better understand the value of knowledge, while the university is in a relatively weak position and will take some technological protection behaviors, which may have a negative impact on the spillover of knowledge. To promote the healthy development and virtuous cycle of the cooperative relationship between universities and enterprises, and form an effective innovation network, the government should create a good environment and conditions for innovation cooperation and commercialization, and provide services for promoting the knowledge production and technology diffusion of universities, as well as the communication and cooperation between universities and enterprises.

In addition, the market-oriented mechanism of enterprise technological innovation and operation should be established. The more effective influence of university knowledge spillover on enterprises' technological innovation is based on the market-oriented orientation of enterprises' innovation and management. If enterprises do not change the linear economic model or give up sustainable product innovation design and production mode for short-term benefits, then, in the long run, enterprises' demand for knowledge and innovation will be limited. In this way, the spillover effect of university knowledge and science and technology will not happen, and the potential of university science and technology resources to promote CE will not be brought into full play.

2.2 Theoretical framework of university CE-related asset management system towards CE model

The above research shows that university education and scientific research assets have great potential to promote the CE transition. So, it is necessary to build a theoretical framework of CE for integrating the functions of universities in CE implementation to exert significant influence.

Concept of CE-related university assets. To better describe the CE theoretical framework for universities, this study provides a definition of the university assets by considering the discourse on the CE (Kirchherr et al., 2017; Rossi et al., 2020) and the concepts of assets (Zhang et al., 2020; Ma, 2020). This study define CE-related university assets as all types of resources that formed during the course of the university's development, owned or actually controlled by the university, and are expected to facilitate the transition to a CE model in the use process. CE-related university assets are the basis for universities to implement various CE activities, and an important indicator for measuring and evaluating a university's CE performance.

Specifically, this novel concept contains four basic elements. The first is that the ownership subject of the CE-related university assets is the university. The second is that the forms of the assets are diverse, examples include tangible assets, intangible assets, and fixed assets. The third is that the use process of the assets should follow the 3Rs principles of the CE. The fourth is the orientation of the assets should include universal CE policy goals.

Compared with other university assets, this study argues that there are unique characteristics exclusive to CE-related university assets, including non-profit status, technological innovation, education, propagation, and efficient use of resources. All these attributes are significant factors for achieving the goals of a CE, see Figure 2.5.

- Non-profit attribute. It is stipulated that no organization or individual may establish educational institutions for profit in China (PRC MOE, 1998). Different from enterprises and other entities pursuing the goal of profit maximization, universities mainly focus on social benefits and public services as their ultimate goal. Therefore, CE-related university assets are non-profit.

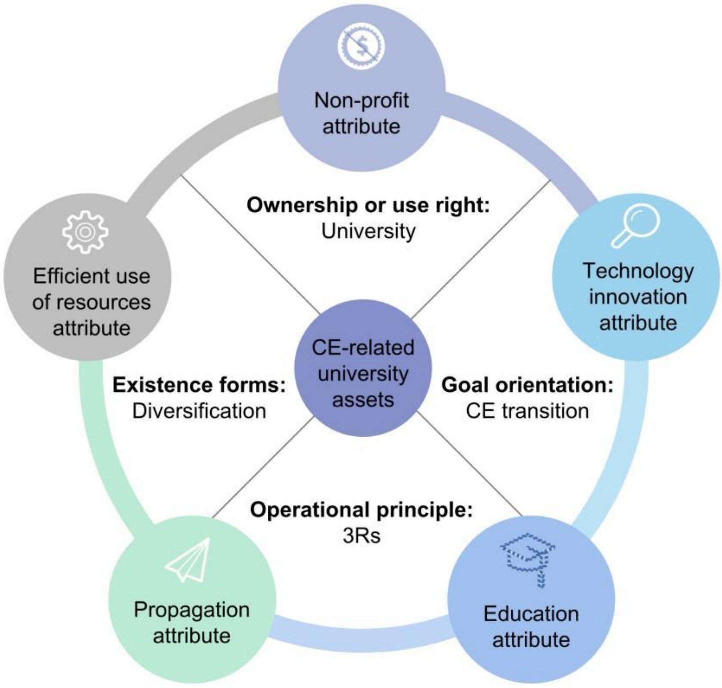

Figure 2.5 - The basic elements and attributes of CE-related university assets.

Source: prepared by the author

- Technology innovation attribute. As one of the main execution subjects of research and development (R&D) activities in China, universities have a significant number of research teams, experts, scholars, and postgraduate students, who promote the vigorous development of scientific research assets in universities (Yin & Shen, 2005). It is evident that universities are the dominant contributors to national scientific and technological output and achievements.

- Education attribute. Universities are significant bases for cultivating talent, which has abundant educational assets such as lectures and other teaching resources. These tangible and intangible educational assets could cultivate and transport a significant amount of talent for society, and bring in many practitioners with CE values and professional CE talent for various sectors of society. Also, CE practice in universities has an implicit education effect on students.

- Propagation attribute. Higher education institutions have great social influence in spreading culture and values, and their propagation activities for the values and value judgment could directly affect the thoughts, attitudes, and behaviors of members of society (Zhao & Zhang, 2012). Universities can disseminate pro-circular values to society through lectures, teaching activities, students' social practice and volunteer service activities, and graduate employment in various industries.

- Efficient use of resources attribute. The essence of the CE model is to improve the efficient use of resources to achieve the goal of coordinated development of environmental protection and economic development. CE-related university assets are oriented by efficient use of resources; for example, textbook recycling and a paperless office system could improve the rate of resource utilization and reduce resource waste.

Classification system of CE-related university assets. To further clarify the extension and the specific orientation of CE-related university assets, this study establishes a multi-dimension classification system according to different features, see Table 2.11. This system is beneficial for decision-makers to have a better understanding of the various categories and usage rules of CE-related assets, so as to conduct scientific top-level design and better propel the CE practice on campus. It could also help the participants of CE activities to cotton on the range of CE-related assets from multiple perspectives so that they could be able to clarify their responsibilities and striving direction in CE implementation.

Table 2.11 - The classification of CE-related university assets

Classification feature	Types of CE-related university assets
By application	1. Scientific research CE-related assets 2. Education CE-related assets 3. Operation CE-related assets
By morphology	1. Tangible CE-related assets 2. Intangible CE-related assets
By formation method	1. Innate CE-related assets 2. Developed CE-related assets
By cost level in the implementation of the CE	1. High-cost CE-related assets 2. Low-cost CE-related assets
By method of participating in the CE	1. Direct CE-related assets 2. Indirect CE-related assets

Source: prepared by the author

First, according to the application, this study proposes to classify CE-related university assets into scientific research, education, and Operation CE-related assets. Scientific research CE-related assets refer to scientific and technological support that can provide green and innovative technologies for the implementation of the CE through research and the integration of production, education, and research. Education CE-related assets are educational resources that can cultivate CE professional talent for the national CE strategy, as well as improve CE awareness and knowledge of college students and the public. Operation CE-related assets are the physical campus resources that can be explored in CE practice that are managed by universities' operations departments, for instance, the development of a shared cycling system on a university campus. Many idle bicycles due to different reasons, such as being abandoned by graduates, could be regularized and conducted with scientific management by the university logistics department to establish a free shared cycling system on campus. This system that reflects the attributes of CE-related assets could not only avoid the consumption of new bicycles to reduce resource waste but also realize the refurbishment and reuse of idle bicycles to improve the efficiency of resource utilization, see Figure 2.6.

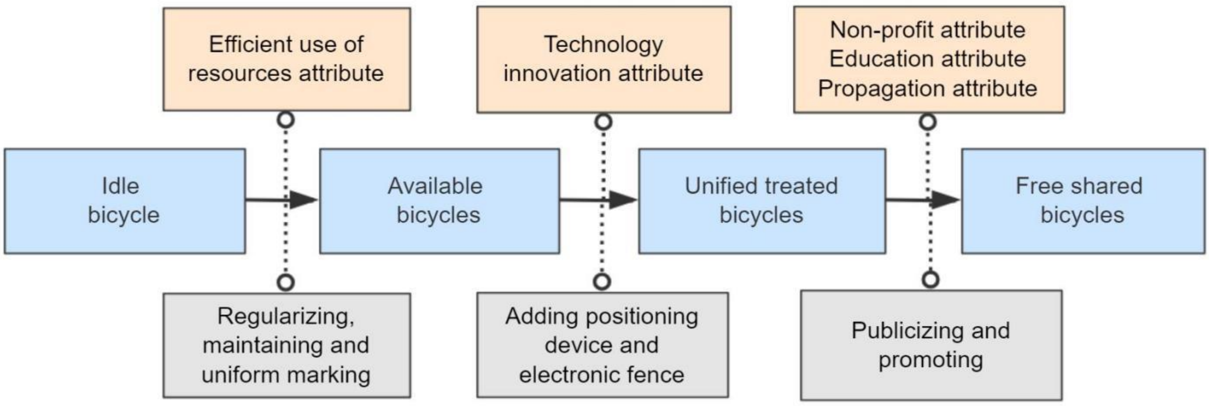

Figure 2.6. Flow diagram of the establishment of campus shared cycling system

Source: prepared by the author

In addition, this study proposes that CE-related university assets should be classified into innate and developed CE-related assets in line with different methods of formation. Developed CE-related assets must be created, developed, or transformed artificially in a later use stage to meet the needs of the CE transition, such as research and creation of green materials and green products, and exploitation and construction of the CE curriculum. Different from developed CE-related assets, innate CE-related assets are assets that are pro-circular in the early stage of introduction or purchase, whose nature does not need to be acquired through post-processing and creation, such as green office supplies and textbooks and learning materials. Specifically, books and learning materials have distinct characteristics that include easy to preserve, high durability, and easy to identify (unique ISBN code), so the second-hand book trade is always regarded as a typical representative of CE practice. Universities could apply the technical means to establish a free internet second-hand book trading platform for teachers and students with the adoption of a more flexible C2B2C (Customer to Business to Customer) model, so as to realize the reuse of books to improve the utilization efficiency. Meanwhile, CE information and ideas could be spread through this learning material recycling system to attract more users to participate in the recycling activities, see Figure 2.7.

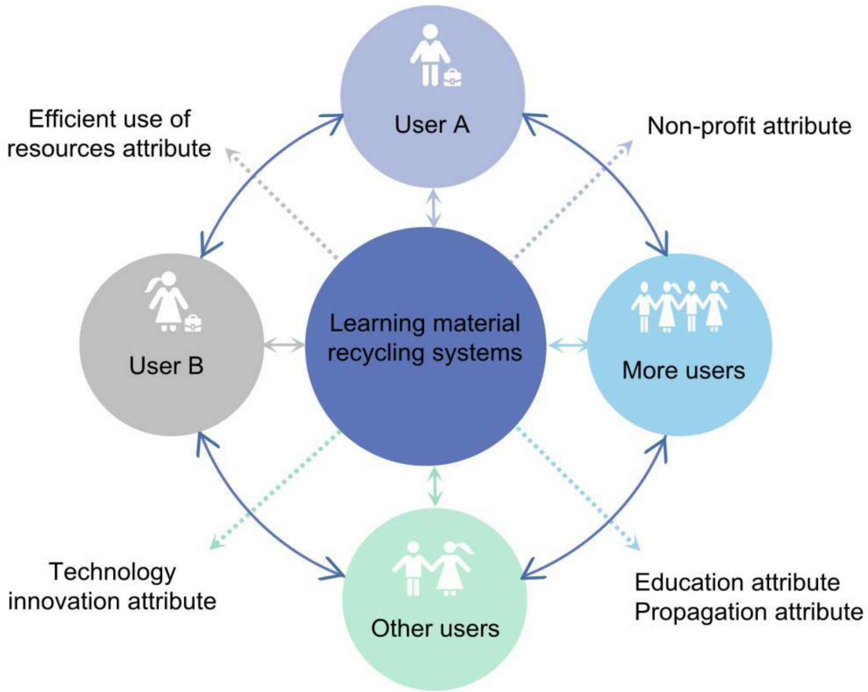

Figure 2.7 - Learning material recycling system based on the internet platform

Source: prepared by the author

Based on the morphology, this study suggests dividing CE-related university assets into tangible and intangible CE-related assets; that is, the former have physical forms, while the latter is invisible. Intangible CE-related assets are unique non-physical resources, which can be used for personnel training, scientific research, and external exchanges, including technological knowledge assets, human resources assets, institutional assets, reputation assets, and other types.

Furthermore, this study argues that CE-related university assets should be divided into high- and low-cost CE-related assets based on the costs of the CE-related assets involved in promoting the transition to the CE model. High-cost CE-related assets require universities to spend a certain amount of time and money or effort when developing this type of asset, for example, the construction of a bicycle sharing system and a reclaimed water recycling system. Low-cost CE-related assets do not cost too much time, money, or effort, or are too inconvenient or even provide good benefits, such as the development of general CE education or recycling of learning materials.

Last, in terms of the different ways of promoting CE performance, this study categorizes CE-related university assets into direct and indirect CE-related assets. The former directly participate in or promotes the implementation of the CE, such as the CE practice carried out by the asset management department and the operations department. The latter is not directly involved in the implementation of the CE but can provide essential elements that can promote the implementation of the CE, such as educational assets that can improve people’s CE awareness and knowledge. For instance, universities could cultivate CE professionals and implement general education about CE, and then students with professional knowledge and ideas can promote the implementation of the CE through their various pro-circular behaviors.

Content of CE-related university activities. Based on the definition and characteristics of CE-related university assets, CE-related university activities refer to the movements or actions that a university carries out to contribute to the transition toward the CE model with CE-related assets as the core. The essence of

CE-related university activities includes scientific research, education, and concrete practical activities based on the classification of CE-related assets by application, as shown in Figure 2.8.

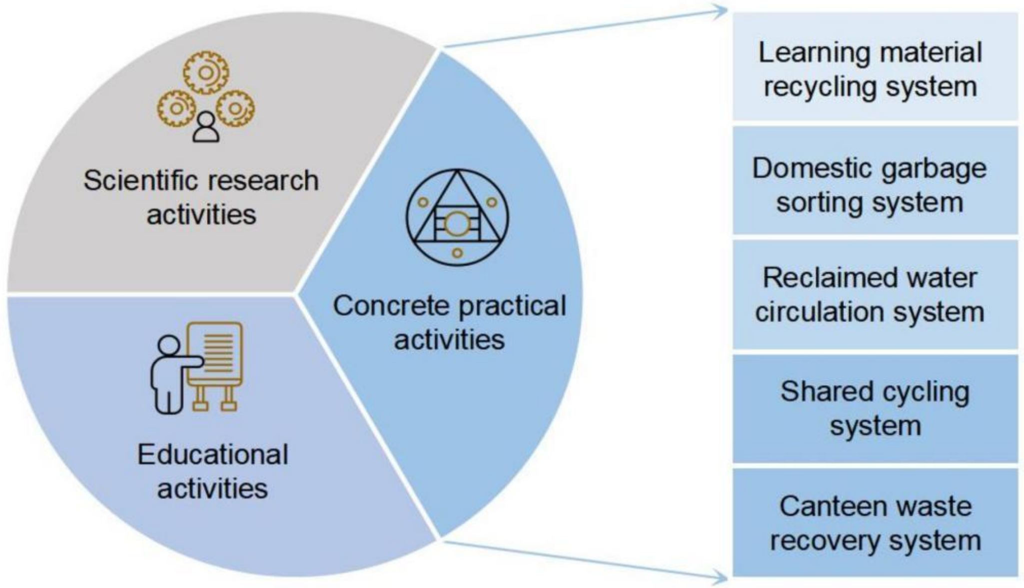

Figure 2.8 - Illustrative content of the key types of CE-related university activities

Source: prepared by the author

- Scientific research activities mainly focus on the research and application of CE technology, including research on green materials and green technology by researchers at the university and the transition of green science and technology achievements from theory to practice through university–enterprise cooperation. China is making green technological progress the main driving force for SD in the future (Jing & Zhang, 2014). Researchers have shown that the effect of guiding R&D toward green technology is significant in promoting the progress of green technology (You & Wang, 2016). In 2019, China invested 23.13 billion euros in R&D at higher education institutions, an increase of 23.2% from 2018 and accounting for 8.1% of the total expenditure. The proportion of the scientific and technological output of higher education institutions is much higher than the proportion of appropriation expenditure on R&D (PRC NBS, 2020). As the dominant contributors to the national scientific and technological output and achievements, universities can provide the necessary green technology support for the transition to the CE model by guiding researchers toward green technology innovation.

Additionally, the application and transition of green technological achievements are as important as the research on green technology. That is, achievements with the practical value generated in the university laboratory should be put into practice for subsequent test, development, application, and popularization. Cooperation between universities and industries is vital to realize the transition of green technological achievements. With the increasingly common research on the coordinated development of green technology and economy, the combination of the scientific research advantages of universities and the industrial carrying capacity of enterprises can effectively promote the implementation of the CE to close the gap between theory and practice.

- Educational activities mainly refer to the education and dissemination of the CE concept to students as well as society, which includes the cultivation of CE professionals and graduates with CE values for society, and the dissemination of the CE idea to the public. In 2019, there were 2,688 general higher education institutions, with a total of 1.74 million full-time teachers, 30.315 million students and 7.585 million graduates at the undergraduate level, and 2.863 million students and 0.64 million graduates at the postgraduate level (PRC NBS, 2020). Colleges and universities play an irreplaceable role in environmental education by offering sustainability courses in a wide range of disciplines and departments (Coleman & Gould, 2019).

However, according to the list of newly registered undergraduate majors published by the Ministry of Education every year, until 2019, only 49 colleges and universities in China offered a Resource Recycling Science and Engineering major, an emerging major approved by the Chinese Ministry of Education in 2010 to meet the urgent demand for talent in the implementation of the CE strategy in China (Qu et al., 2020). To solve the problem of the shortage of CE professionals, universities could attach importance to CE training for educators so that they could effectively convey the correct CE message through their course teaching. Moreover, it is necessary to strengthen the structure of the CE major and formulate scientific curriculum training programs to improve the training of CE talent. The graduates with CE degrees hired by enterprises can bring sufficient CE concepts and creativity to enterprises. Moreover, general education could be universalized to cultivate undergraduates with CE awareness and knowledge, who can spread CE values to surrounding communities through social practices in the community and guide residents to form green consumption habits. Graduates with CE awareness and knowledge are potential green consumers and CE practitioners, who can also disseminate CE values in their areas of expertise and their daily lives after they graduate.

- Concrete practical activities refer to concrete CE practices on campus which consist of various resource recycling systems for achieving the CE, as well as direct use of a university's CE-related assets. Taking learning resources as an example, a survey of Wuhan University of Technology students showed that 85.6% of the respondents disposed of these post-use learning resources as waste paper rather than recycling them as reusable textbooks (Du, 2016). To advocate for recycling and reuse of textbooks and other learning materials, universities could organize on and offline learning material recycling systems (Guo, 2014). In addition, various resource recycling systems could be established on campus, such as a domestic waste sorting system, a reclaimed water circulation system, a shared cycling system, and canteen waste recovery systems.

Additionally, an internal CE-related assets management network could be set up to monitor the efficient use of assets at every stage of their lifecycle according to CE principles. From the purchase of assets as a starting point, priority could be given to the use of environmentally friendly materials and products. In the process of using such products and processes, it is necessary to fully consider whether they pollute the environment and how to control pollution and other negative factors. The possibility of multi-level recovery of waste and other related factors would be considered in the process of asset scrapping and waste recovery.

These both concrete and practical activities could exert an edifying influence on leaders and students and contribute to the realization of transformative CE learning and education.

Theoretical framework design of university CE-related asset management system. CE-related university activities involve a wide range of areas, including scientific research, education, undergraduate social practice, and operations, so the subjects of CE-related university activities are more extensive, which means all university members need to be the subject of CE-related activities. Therefore, the CE theoretical framework would include all university members with widespread knowledge as the key to successfully disrupting the linear system. In particular, the subjects mainly include researchers and lecturers of relevant teaching departments, undergraduate social practice departments, and students with CE awareness and knowledge, as well as the operations department and its staff. It should be noted that not all university staff are born with the CE knowledge and ability to carry out CE-related activities, so CE training for them is the precondition for the implementation of all kinds of CE-related activities in this framework.

On this basis, university researchers could take advantage of scientific research, set up teams to carry out CE policies and theoretical research, focus more on green technology design and technological innovation, and break through the existing bottleneck of CE technology. Through curriculum teaching activities, lecturers could aim to cultivate CE professionals for enterprises and college students with CE awareness and knowledge who could disseminate CE education to society with routine social practices. In addition, operations managers and staff could explore CE practices on campus by constructing resource circulation systems and monitoring their operations. This practical exploration not only provides a direct and effective reference to the implementation of the CE in society but also affects the public's lifestyle in an all-around way, and forms the ecological culture within universities, thus contributing to the formation of a good ecological culture for society.

Based on the elaborations above, this paper proposes the theoretical framework of CE-related university activities that could provide many benefits for promoting the CE transition, including the construction of the CE culture in society, green manufacturing and technological innovation in enterprises, green consumption, and participation in supervision of the public, see Figure 2.9.

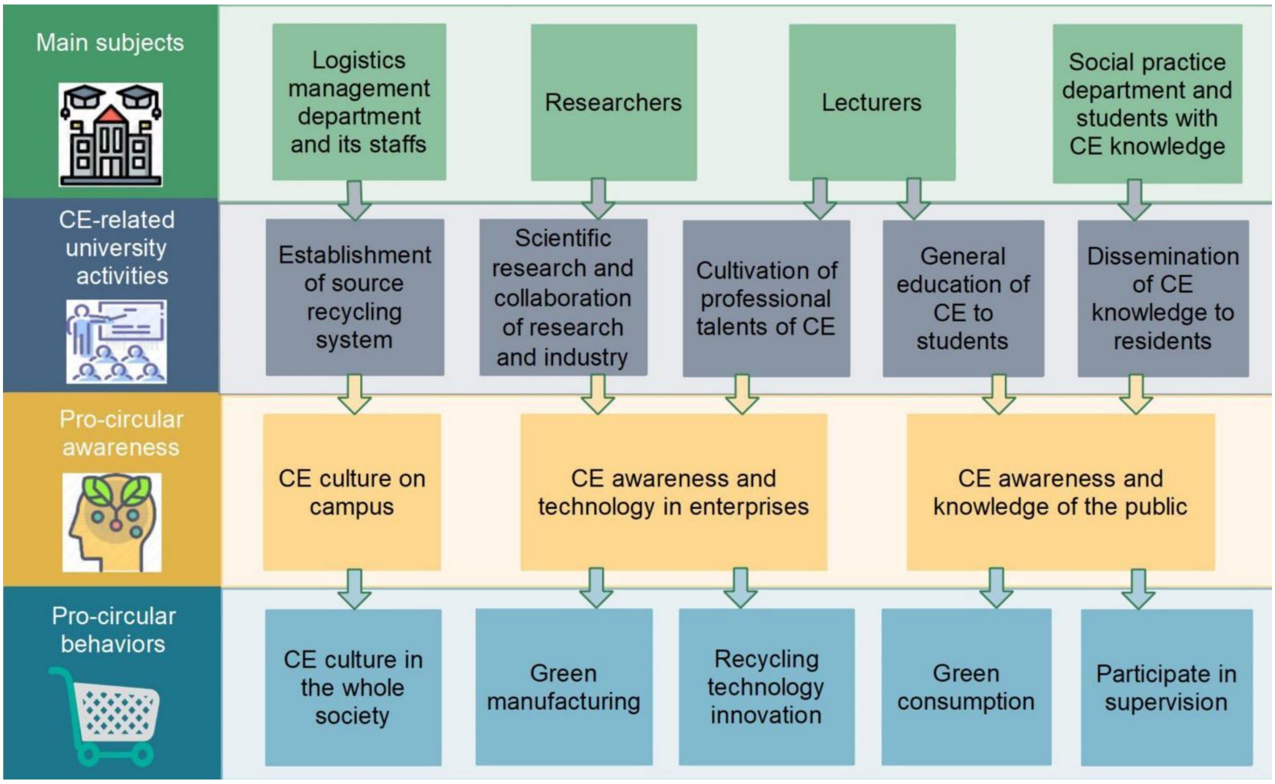

Figure 2.9 - Theoretical framework of university CE-related activities

Source: prepared by the author

In this framework, the subjects of CE-related university activities are the major factors, because their attitude and behaviors directly determine the effect of CE-related activities. Therefore, the CE training for university faculty and staff is of great significance. Fortunately, there is no need to impose excessive coercion or inducement on them except the training, because scientific research and teaching are crucial parts of universities' routine work. All they need to do is to integrate CE information into their daily work. Moreover, it is very convenient and effective to spread CE concepts to community residents by taking student social practice activities as an opportunity to implement education, because social practice activities during vacations and daily volunteer social service activities at every university in China have become a tradition (Wang, 2014). In addition, implementing CE practices on campus requires only the operations department to adjust the working concepts toward the goal of the CE to establish various resource recycling systems, which will not only make the operations work more efficiently but also form an intangible CE cultural atmosphere that can exert a subtle influence and implicit education to students.

In other words, while participation in the CE practice is the responsibility of all members of the university, they will not suffer additional work stress or role load but can obtain many benefits in the process. In any case, the theoretical framework of CE-related university activities is a low-cost and high-profit way to promote the transition to a CE model (Qu, et al., 2021).

2.3 Evaluation method of university CE-related asset management performance

Basic requirements and principles of index system construction. The theoretical framework of CE-related assets proposed in this study is based on the theory and activities of SD. Similarly, the CE-related asset management evaluation index system of the university is also based on the sustainable campus evaluation system, so that the university can promote the development of campus CE under the existing building environment and conditions to achieve the goal of maximizing resource utilization and minimizing waste. In terms of the specific content, objectivity and validity are the basic requirements of constructing an index system. At the same time, the following principles should be followed in the process of index system construction:

- **Principle of integrity.** The index system requires complete and comprehensive indicators, including indicators reflecting various types of CE-related asset management of the university, to form a complete performance evaluation index system.

- Principle of hierarchy. The index system should form different levels of indicators, the levels should adapt to each other and have consistency so that it has the corresponding guiding role. Each upper index has its corresponding lower index, forming a clear hierarchy.

- Principle of scientificity. The evaluation index system of green campus is constructed by the scientific method and scientific index and planning is helpful to realize the planning goal. The system composed of multiple indicators should be classified and normalized, so that the meaning range of each indicator is clear, the final result dimension is consistent, and the comparability of the indicator system is realized.

- Principle of incentive. The incentive principle is to ensure that the selected indicators have the function of continuity and guidance. The original intention of establishing the evaluation index system is to guide and encourage universities to advance towards the direction and goal of social CE in the future development process, rather than to select universities with the ability and level of building CE. In this sense, evaluation indicators should reflect and play a guiding and motivating role for universities.

- Principle of selectivity. In the selection of the evaluation index system, this study should adopt a practical and realistic attitude, and pay attention to the selection of those indicators with reality, independence, and necessity. At the same time, the representativeness and comparability of indicators should also be considered, so that the index system can truly reflect the comprehensive management performance of CE-related assets in universities.

- Principle of operability. The principle of operability requires that the characteristics and differences of universities of different levels and categories should be considered in the evaluation process. The evaluation of the development degree of the university CE-related assets should be combined with the quantity and quality, qualitative and quantitative, and given the corresponding weight to carry out the all-around evaluation. That is to say, the formulation of the index system should ensure the combination of simplicity and practicality, so as to achieve the purpose of combining difference with operability.

Evaluation method of sustainable university management. The colleges and universities have gradually formed the corresponding evaluation mode while implementing the sustainable plan. The most influential is the University Sustainability Report Card (ASEI, 2011) and the UI Green Metrics World University Rankings (UI, 2022), both of which focus on ranking or rating universities that are striving to contribute to sustainability, assessing their contribution to sustainability, to encourage universities to work towards the UN's SDGs. The categories of evaluation indicators are shown in Figure 2.10.

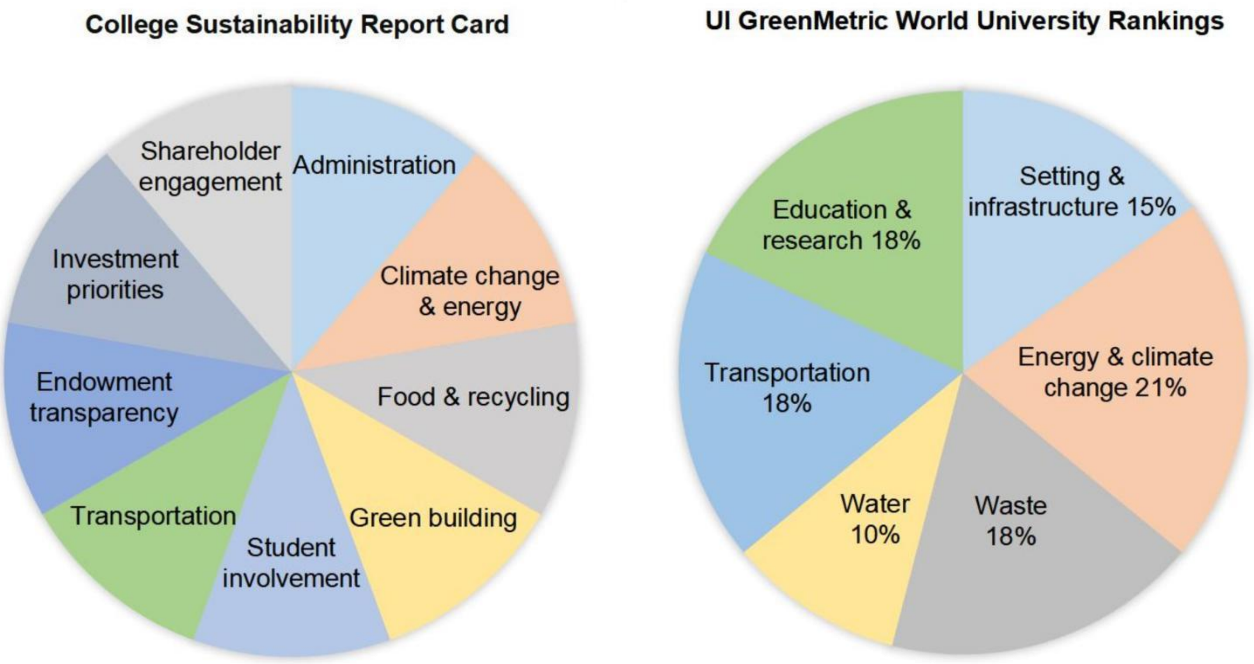

Figure 2.10 - Indicator categories of CSRC and UIGWUR

Source: prepared by the author

The CSRC report, published by the American Sustainable Endowment Institute, aims to rate the sustainability of 322 universities in the US and eight Canadian provinces based on nine sub-indicators. UIGWUR was launched in 2010 by Universitas Indonesia and is widely regarded as the most authoritative assessment of university sustainability efforts around the world. The tool conducts online surveys and ranks the sustainability and policies of 956 participating universities from 80 countries across six sub-indicators.

In this study, the UIGWUR index system was used for detailed analysis, which is not based on any ranking system. Some existing sustainability assessment systems and academic ranking mechanisms were considered for reference during the design phase of UIGWUR, such as the Holcim Sustainability Awards, LEED, CSRC, the Times Higher Education World University Rankings, the QS World University Rankings, Academic Ranking of World Universities. The University of Indonesia has been a member of the International Ranking Expert Group since 2011. Therefore, in the early stage of the design of the competition, experts and scholars related to university rankings and sustainability topics were invited to assist, such as university rankings seminars and video seminars on sustainability and green buildings.

The concept of SD in the evaluation criteria of green universities in the world mainly includes three main elements, namely, environment, economy, and society. Environmental aspects include the use of natural resources, environmental management, and pollution prevention. Economics involves profit and cost savings. Social aspects include education, community, and social participation. Taking into account the diverse types and diversity of universities around the world, the World green campus Evaluation continues to improve its ranking system in line with new trends in SD topics to ensure practicality and fairness for all participants. The evaluation index has been developed from 23 specific indicators in 5 categories in 2010 to 39 indicators in 6 categories to calculate the score ranking. The latest classification and weighting points are shown in Figure 2.10.

Scores of sub-indicators for each category will be simple counts of things or responses on a scale of some sort. The score of each index is presented numerically for statistical processing. The data acquisition method is mainly based on the self-evaluation questionnaire filled in by each university every year. Here this study lists the scoring details for the waste category so that the rating system can be represented, as shown in Table 2.12.

Table 2.12 - Category and Indicator Point of Waste in UIGWUR

No.	Category and Indicator Point of Waste (WS): Total Point=1500, Weighting=18%					
WS1	Recycling program for university waste. (Point=300)					Score
	None	Partial (1-25% of waste)	Partial (>25-50% of waste)	Partial (>50-75% of waste)	Extensive (>75% of waste)	
	0	0.25×300	0.50×300	0.75×300	1.00×300	
WS2	Program to reduce the use of paper and plastic on campus. (Point=300)					Score
	None	1 program	2 program	3 program	More than 3 program	
	0	0.25×300	0.50×300	0.75×300	1.00×300	
WS3	Organic waste treatment. (Point=300)					Score
	Open dumping	Partial (1-25% of waste)	Partial (>25-50% of waste)	Partial (>50-75% of waste)	Extensive (>75% of waste)	
	0	0.25×300	0.50×300	0.75×300	1.00×300	
WS4	Inorganic waste treatment. (Point=300)					Score
	Burned in open	Partial (1-25% of waste)	Partial (>25-50% of waste)	Partial (>50-75% of waste)	Extensive (>75% of waste)	
	0	0.25×300	0.50×300	0.75×300	1.00×300	
WS5	Toxic waste treatment. (Point=300)					Score
	Not managed	Partial (1-25% of waste)	Partial (>25-50% of waste)	Partial (>50-75% of waste)	Extensive (>75% of waste)	
	0	0.25×300	0.50×300	0.75×300	1.00×300	
WS6	Sewage disposal. (Point=300)					Score
	Untreated into waterways	Treated conventionally	Treated technically for reuse	Treated technically for downcycling	Treated technically for upcycling	
	0	0.25×300	0.50×300	0.75×300	1.00×300	

Source: prepared by the author based on official website data and information

The final Score is a weighted sum of the original scores for each category. The calculation formula is as follows:

$$S = \sum_{i=1}^{m} W_i S_i \tag{2.4}$$

Where, $S_i = \sum_{j=1}^{n} S_{ij}$, m represents the number of categories of indicators (m=6). W_i represents the weight points of the category (i). S_i represents the original score of categories (i). n indicates the number of lower-level indicators of a category. S_{ij} represents the original score of the indicator (j) in category (i), which is the number of points corresponding to an option.

Green campus evaluation index system in China. As the establishment of

SD universities in China is still in its infancy, Chinese universities have little participation in the worldwide SD university rankings. Some universities have special departments responsible for implementing ESD, such as the Green Campus Office of Tsinghua University and the Campus Management Office of Tongji University, while many Chinese universities have not yet set up special institutions to coordinate and organize these actions. In recent years, the Chinese government has gradually attached importance to the construction of green campuses and put forward clear requirements and relevant standards in promoting the construction and development of green campuses, such as GCES and GCCAP.

By comparison, the GCCAP only provides the general index as a reference for each region to formulate a local implementation plan, the weight and scoring method of each index are not clearly specified. The index system of GCES is more perfect, in which the evaluation system of green campuses of universities is stipulated and elaborated with five indicator categories, which contain control items and scoring items. The control items are the basic condition that must be met, so no scoring is performed. The total score for each category of indicators is 100 points, for example, the indicator of Operation and Management includes four control items and 12 scoring items, as shown in Figure 2.11. Therefore, this study mainly carries out a detailed analysis of the GCES index system.

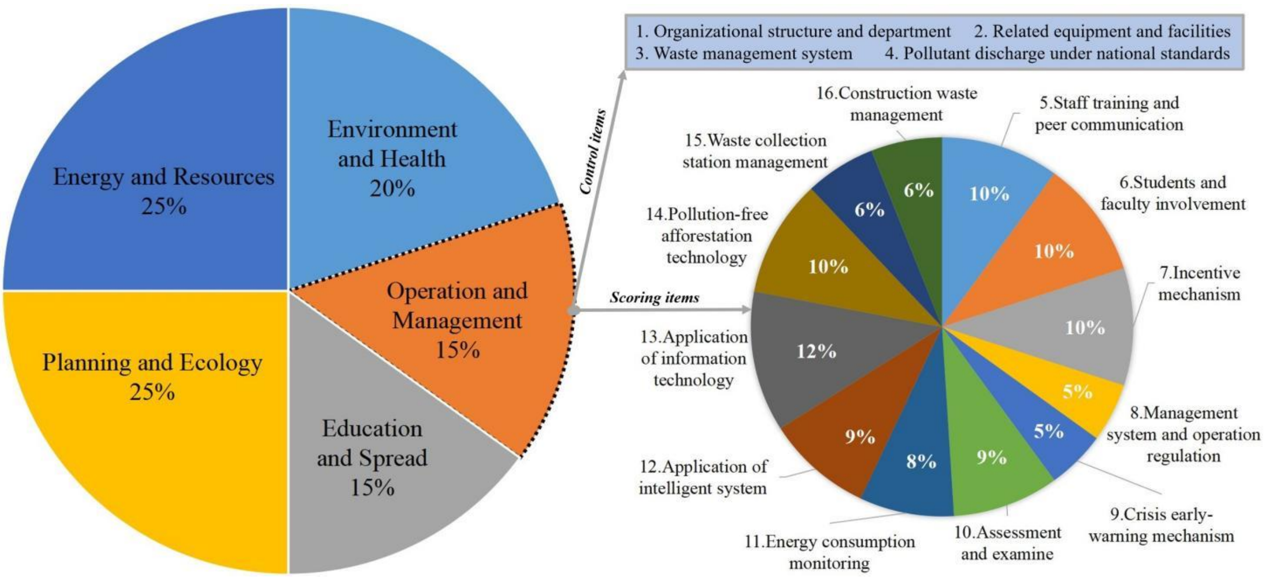

Figure 2.11 - Indicator system and the subitems in GCES

Source: prepared by the author

In addition, the GCES also set extra points for the characteristic and innovative activities except for the five basic indicators, that is, some additional points can be added. Therefore, the total score of the green campus evaluation should be the sum of the scores of the five main indicators multiplied by their respective weights, and then add the additional score of the extra points.

The calculation formula is as follows:

$$Q = \sum_{i=1}^{m} W_i Q_i + Q_6 \tag{2.5}$$

Among them, W_i is the weight of category i, Qi represents the raw score for category i, Q6 score points for bonus points. Green campus evaluation grade is divided into three grades according to Q value: one star (≥80), two stars (≥60), and three stars (≥50). The three grades should meet the requirements of all control items of each index, and the original score of each index should not be less than 40 points.

Similar to UIGWUR, the evaluation method stipulated in GCES also requires universities to conduct self-evaluation according to the index system and submit questionnaires and related report documents to the evaluation agency for review. In addition, both of the scoring methods are weighted summation methods. The difference is that the final evaluation result of GCES is to determine the evaluation grade rather than the university ranking.

Establishement of evaluation method and implementation standards. The essence of building the CE-related asset management evaluation index system is to establish an information feedback channel for the majority of participants to the relevant university CE-related work, and give an effective evaluation of the university CE-related asset management system according to the information feedback, so as to improve the performance of university CE-related asset management and promote the realization of CE development goals.

The CE theoretical framework proposed based on university assets includes all university members with widespread knowledge as the key to successfully disrupting the linear system. Therefore, this study proposes the construction of an evaluation index system based on full participation, which means that all faculty and staff should participate in the content and process monitoring as evaluation subjects to ensure the effectiveness of the evaluation index system. Obviously, this method is more reliable than the traditional method of self-evaluation to the assessor for review.

- Basic contents of the evaluation index system. CE-related asset management includes education, scientific research, campus practice activities, and other diversified objectives. Therefore, the evaluation of the CE-related asset management system should select appropriate evaluation indicators according to the objectives. Referring to the green degree evaluation index system commonly used in China, the evaluation index system of CE-related asset management constructed in this study includes 3 criterion layer indicators and 29 index layer indicator levels, such as CE education, CE research, and CE practice.

From the perspective of content, CE education is to integrate CE-related knowledge and ideas into the curriculum plan, combine teaching with learning, and teach students the knowledge and skills to participate in CE activities. CE education has eight evaluation indicators, including CE professional courses, general education courses, practical courses, special lectures, theme activities, social practice participation, community volunteering participation, and campus media CE special report.

Moreover, the application of CE scientific research affects the route of innovation ideas and innovative technology and the change of enterprise operation model and social business model. There are also eight indicators for evaluating CE research, including published academic papers, published works, project approval situation, patent application, patent revenue, technology transfer contract, and technology transfer revenue. As for the CE practice on campus, it mainly consists of three main types of activities that correspond to the CE principles, namely reduce activities, reuse activities, and recycle activities. The corresponding indicators are related to specific campus practices, such as the paperless office initiative and reclaimed water program, see Table 2.13.

Table 2.13 - Evaluation index system of CE-related university assets management performance

Target layer	Criterion layer (weight)	Domain Layer (weight)	Index layer (weight)
Circularity degree D	CE education (30%) D1	Curriculum education (10%)	CE professional courses D1-1
			General education courses D1-2
			Practical courses D1-3
		Extra-curricular education (10%)	Special lecture D1-4
			Theme activities D1-5
		Cultural communication (10%)	Social practice participation D1-6
			Community volunteering participation D1-7
			Campus media CE special report D1-8
	CE research (30%) D2	Academic achievements (10%)	Published academic papers D2-1
			Published works D2-2
			Project approval situation D2-3
		Patented achievements (10%)	Patent application D2-4
			Patent granted D2-5
			Patent revenue D2-6
		Industry-university-research cooperation (10%)	Technology transfer contract D2-7
			Technology transfer revenue D2-8
	CE practice (40%) D3	Reduce activities (15%)	Campus shared bike program D3-1
			Paperless office initiative D3-2
			Campus anti-plastic campaign D3-3
			Empty plate campaign D3-4
			Renewable energy program (Solar hot water) D3-5
		Reuse activities (15%)	School second-hand product trading platform D3-6
			Online platform for second-hand product trading on campus D3-7
			Reclaimed water program D3-8
			School computer maintenance program D3-9
			Express packaging recycling initiative D3-10
		Recycle activities (10%)	Waste separation management program D3-11
			Kitchen waste recycling program D3-12
			Electrical and electronic products recovery D3-13

Source: prepared by the author

- Process monitoring model. In many countries around the world, top-down instruction and bottom-up participation are important elements in the operation of SMS. In the sustainable university management model and organizational structure, the way and degree of participation of various stakeholders will greatly affect the effect of management. Only relying on the top-down model is easy to fail, because it may lack the promotion of specific subjects, and lack of the sincere understanding and support of all teachers and students so that the implementation of this responsibility becomes a mere formality. However, the defect of the bottom-up participation mode is that stable output may not be guaranteed due to the lack of institutions. University CE-related asset management must adopt bi-directional hybrid management, that is, the management mode of top-down administrative instruction and bottom-up full participation is adopted to guarantee the realization of university CE goals.

Therefore, before evaluating the performance of CE-related asset management, some control items should be considered to make the index system more perfect. This is similar to the control items stipulated in the national standards GCES. Although these control items are not regarded as scoring indicators, they are the basic conditions that universities must meet before participating in scoring. These controls include:

- The university has a clear overall SD plan/ CE development plan.
- The development of school plans should involve the full participation of teachers and staff representatives.
- The annual CE development goals of colleges and universities are formulated and the responsibilities of departments and persons are identified.
- Institutions for CE-related asset management and operation should be established in universities, and the responsibilities of departments and positions should be clarified.
- The CE-related asset management operation department has the participation of some teachers and student volunteers.
- Colleges and universities have CE budgets and publish expenditures.
- Formed campus CE practice project and regularly announced the project's progress.
- Publish annual target achievement at the end of the year.
- Prepare CE-related asset management annual report at the end of the

year and make it public.

- Publicize the achievements of campus CE promotion within a certain social scope and accept social supervision

- Evaluation of circularity degree. To make the operation simple, the percentage weight summation method is adopted by integrating the Delphi method and AHP method to obtain the evaluation score of the university, which is used to determine the university's final circularity degree. First of all, the weight of the individual is obtained by calculating the average value according to the expert's percentage evaluation results of all indicators. Then, all kinds of relevant personnel of CE-related asset management, including teachers, students, administrative staff, and middle and senior leaders, will score each indicator according to the percentage system. Finally, the multi-objective linear function weighting method is adopted to calculate the circularity degree of CE-related asset management performance in the university, and the calculation formula is as follows:

$$D = \sum_{i=1}^{m} \sum_{j=1}^{n} W_{ij} D_{ij} \qquad (2.6)$$

Where m is the indicator number of the criterion layer (m=3), and n is the indicator number of the lower index layer. W_{ij} is the weight of the corresponding indicator in each indicator layer, and D_{ij} is the specific score of a single indicator for each index layer.

According to the above method, the total score of management performance evaluation score in a certain university could be calculated simply and quickly, which corresponds to different levels of circularity degree in the grading standards, see Table 2.14.

Table 2.14 - Circularity degree division for management performance of CE-related university assets

Level	No circularity	Low circularity	Moderate circularity	High circularity	Deep circularity
D value	0-20	20-40	40-60	60-80	80-100

Source: prepared by the author

Conclusions to section 2

In section 2 "Construction and evaluation of CE-related asset management system in Chinese universities", the educational and scientific potential of Chinese universities in improving CE performance is explored based on the analysis of relevant data in various universities and spatial knowledge spillover theory. This study attempts to design the theoretical framework of the CE-related university assets management system based on full consideration of CE-related university assets and CE-related activities. Also, the approach to establishing the CE-related assets management system in universities is explored. The following conclusions are obtained.

1. With the synthetic analysis of the current status of the major of UCEE in Chinese universities, it is highlighted that the educational potential of Chinese universities in CE implementation is mainly reflected in the aspects that include promotion of specialty development and talent cultivation, improvement of the curriculum setting, enhancement of education function of the hidden curriculum, enrichment of general education of CE, construction of teacher team of CE related majors, and the extension of the influence and scope of education radiation.

2. The empirical analysis of the spillover effect of university knowledge space is conducted to analyze the scientific potential of universities. It is verified that university knowledge innovation has a considerable impact on the innovation activities of enterprises in the neighboring region. In particular, the comprehensive output of university knowledge innovation is closely related to the innovation and management of enterprises. Moreover, the university scientific research has significant potential on promoting the technological innovation activities of universities and enterprises in surrounding areas. Based on the analysis, targeted suggestions for the stakeholders on exerting the potential of university research assets are proposed.

3. The connotation of CE-related university assets is provided as a novelty, which refers to all types of resources that formed during the course of the university's development, owned or actually controlled by the university, and are

expected to facilitate the transition to a CE model in the use process. Specifically, this novel concept contains four basic elements, including the ownership subject of the assets, the forms of the assets, the use process of the assets, and the orientation of the assets. Further, the classifications of these CE-related assets are provided, as well as the attributes of CE-related university assets, such as non-profit status, technology innovation, education, propagation, and efficient use of resources.

4. A systematic theoretical framework for CE-related university activities is developed based on the classification and attributes of CE-related university assets, which integrates various CE activities in a unified management system rather than simply patching them together in expanding the university's influence in the CE transition. There are four kinds of activities toward the CE transition in the theoretical framework. The first is scientific research CE-related activities, which take researchers as the main subject in the implementation and can provide CE technical support for enterprises based on scientific research CE-related assets. The second is education CE-related activities, which take lecturers as the central implementation subject who can cultivate CE professionals and implement general CE education for college students. The third is derived from the previous one, which takes college students as the main subject who can diffuse the CE concept to society through their routine social practices and other volunteer activities. The fourth is concrete CE practical activities with operations managers and staff members as the main subject, who could provide the reference for CE practice at the social level and contribute to the construction of CE culture in society based on Operation CE-related assets.

5. By analyzing the evaluation methods of sustainable universities, an evaluation method and implementation standards of CE-related university assets management performance are created based on full participation theory. In this evaluation index system, all faculty and staff should participate in the content and process monitoring as evaluation subjects to ensure the effectiveness of the evaluation index system, which is more reliable than the traditional method of subjective self-evaluation. The basic contents of this evaluation index system

mainly include the target layer, the criterion layer, the domain layer, and the index layer, and each indicator is assigned its weight. It is determined that the circularity degree is evaluated based on the final score calculated by the specified formula, such as no circularity (0-20), low circularity (20-40), moderate circularity (40-60), high circularity (60-80), and deep circularity (80-100).

SECTION 3: CASE STUDY OF WASTE MANAGEMENT PROGRAM IN CHINESE UNIVERSITY

3.1 Advancing waste management program at H University

As mentioned earlier, the university management system of CE-related university assets includes the construction of multiple sub-systems. It must be a vast project to study all the subsystems. Therefore, this study has selected the construction of campus waste separation and recycling management project as a case study for empirical research and attempt to achieve the enlightenment effect of drawing inferential conclusions in practice.

The reason for choosing the waste management project for the case study is that the waste management project in universities has always been one of the important contents and main indicators for the creation of green campuses. Moreover, waste separation and recycling based on the principle of CE is both the main development trend of the whole society's domestic waste management mode and an important practice for all people to participate in practicing the principle of CE (Gan, 2020). However, in the process of the Green Campus Initiative in China, the lag of the campus waste management program is the development bottleneck of many universities. To improve the performance of waste management programs in Chinese universities, this study attempts to describe the ideal shape of an effective university waste management program through empirical study, thereby providing references for other universities struggling with waste management.

To accelerate the implementation of the waste management program at universities, this study conducted a case study to analyze the experience of Leiden University in waste management and the current situation of H University's waste management program in China. Leiden University was chosen because of its outstanding performance in sustainability and its many similarities with H University. This study attempted to provide a comprehensive overview of Leiden University's experiences from the perspective of management including its essential functions of planning, organizing, leading, and controlling. According to the problems existing in the waste management program of H University, some enlightenment could be drawn from the experience of Leiden University. Based on the contrastive analysis, this study proposed some suggestions for the waste management program at H University at the theoretical level, as well as a specific and implementable waste management program for H University.

Experience and enlightenment from the Netherlands. The waste management system of universities is a comprehensive management system that covers the whole process of the generation, separation, delivery, collection, transport, and disposal of all the waste on campus. To better understand and build the waste management system, this study proposes to analyze all the processes from the perspective of management functions. An integrated university waste management system should embody the essential functions of management, including planning, organizing, leading, and controlling. Planning refers to the orientation of the waste management goal and the accomplishing means. Organizing means the corresponding authority institutions and relevant responsible persons set up by universities to achieve the goal of waste management. Leading implies the publicity and education activities or incentive measures taken for the campus units or all teachers and students by the relevant responsible persons to realize the waste management goals. Controlling refers to the monitoring of waste separation activities on campus to correct deviations in time and take measures to ensure the plan's implementation. To assure the long-term and effective operation of the system, universities should fully consider all these factors in the management process.

To explore the standard process of waste management system in practice, the construction of the waste separation management system of Leiden University in the Netherlands was selected for a detailed review. The Netherlands was chosen as the target country because it is one of the first countries to separate waste and one of the best in implementation. Also, the Netherlands has the highest population density in Europe and one of the highest population densities of any country or region in the world. It means that the density of waste producers and throwers in the Netherlands is very high, which has similar problems to China, the most populous country in the world. Therefore, the practice of waste separation in the Netherlands can provide valuable inspiration for the implementation of waste separation management in China.

In choosing the specific university, this study considered Netherlandish universities in the UIGWUR, which has been widely recognized as the most influential evaluation authority that aims to assess the sustainability performance of all universities around the world. A total of seven universities in the Netherlands have participated in UIGWUR since 2017, but two universities dropped out of the rankings during the period, see Table 3.1.

Table 3.1 - Netherlandish universities that participated in UIGWUR from 2017-2020

Netherlandish universities in UIGWUR	Rankings	2017	2018	2019	2020
Wageningen University & Research	Overall Rankings	1	1	1	1
	Ranking by Waste	1	1	1	1
University of Groningen	Overall Rankings	11	7	8	7
	Ranking by Waste	17	34	5	5
Delft University of Technology Tu Delft	Overall Rankings	22	31	32	46
	Ranking by Waste	20	67	35	55
Leiden University	Overall Rankings	49	24	7	8
	Ranking by Waste	22	23	16	6
Eindhoven University of Technology	Overall Rankings	171	--	--	--
	Ranking by Waste	191	--	--	--
Radboud University	Overall Rankings	395	111	--	--
	Ranking by Waste	180	127	--	--
Tilburg University	Overall Rankings	410	464	139	221
	Ranking by Waste	168	258	166	242

Source: prepared by the author based on Archive rankings of UIGWUR (UI, 2022)

Wageningen University & Research has been ranked first in the rankings for nearly 4 years. Nevertheless, this study still chose to focus on Leiden University. Leiden University is currently the oldest continuously functioning university in the Netherlands, which is very aware of handling its responsibilities in the areas of sustainability and has achieved remarkable achievements in sustainable operations. In 2020, Leiden University was ranked 8th overall among all 911 participating universities in UIGWUR and 3rd among all participating universities in the

Netherlands. It is worth mentioning that this achievement of Leiden University is made despite its poor setting and infrastructure condition (ranked 629 in UIGWUR and 5th among Netherlandish universities).

H University in China is similar to Leiden University in terms of setting and infrastructure conditions, such as insufficient open space area, campus forest cover area, and a limited budget for sustainability efforts. This is one of the main reasons why this study chose Leiden University. In addition, after reviewing Leiden University's performance in sustainability, this study found that Leiden University developed Environmental Policy Plan in 2015 and then became very active in sustainability in 2016. From 2017 to 2020, Leiden University's ranking in UIGWUR steadily increased year by year. It is marvelous how much progress has taken place in such a short time. Therefore, Leiden University was chosen to provide references for Chinese universities to accelerate the process of SD in the short term. The other thing this study needs to acknowledge is that Leiden University is very open about its sustainability activities, which demonstrates its ambition to be one of the most sustainable universities in the future and also gives us easy access to detailed information.

- Planning. From 2016 until the end of 2020, Leiden University followed the Environmental Policy Plan 2016-2020 (LU, 2016), which details how it intends to operate to take responsibility in the field of environment and sustainability, including integrating sustainability issues into the education and research and clarifying waste accountability. The new 2030 vision for the SD plan is delayed due to the impact of the coronavirus pandemic and is now being developed.

The waste management program is one of the themes for improving the performance of the environment and sustainability in Leiden University's environmental policy plan. To reduce waste and increase the recycling of reusable resources, Leiden University takes a three-pronged approach to the waste reduction that includes preventing waste, separating waste, and recycling. Among them, preventing waste is the main goal and the most effective approach to reducing the impact on the environment. Providing education in CE and sustainability for students, the primary waste producers, is conducive to achieving the goal. Therefore, Leiden University has developed some ambitions of education and research so that students can learn more about CE and SD during their studies, providing them with the knowledge and value they need to tackle the significant challenges in their future careers, see Table 3.2.

Table 3.2 - Action List of Education and Research in Leiden University from 2016 to 2020

No.	Goal	Responsible for initiation	When
EDU1	In 2018 there will be a clear overview of all the activities in the area of sustainability in teaching and research at Leiden University	HSE	2018
EDU2	In 2018 there will be a communications framework in which this overview can be presented and supplemented in a user-friendly way.	Communication	2018
EDU3	In 2018 the possibilities for including a compulsory general studies core curriculum course on sustainability in every bachelor's curriculum will have been investigated.	Centre for Sustainability	2018
EDU4	In 2018 the possibilities of a "sustainability endorsement" on degree certificates will have been investigated.	Centre for Sustainability	2018
EDU5	From no later than 2018, the Centre for Sustainability will offer a course on "integrating the theme of sustainability in existing curricula" for interested teaching staff.	Centre for Sustainability	2018
EDU6	No later than 2018, one or more workshops will be held in the Lorentz Center to explore how research in the area of the environment and sustainability can be developed further.	Lorentz Center	2016

Source: prepared by the author based on Environmental Policy Plan 2016-2020 (LU, 2016)

In addition, while limiting the amount of waste as much as possible, universities need to sustainably dispose of any waste that is still generated so that raw materials can be recycled back into the supply chain to contribute to a CE. Sending the remaining waste to waste-to-energy plants for incineration is the last way if there is no other option. Similarly, Leiden University's listed the ultimate goals of waste accountability in its environmental policy plan, see Table 3.3. The first two goals correspond to the prong of preventing waste. The WAS1 and WAS2 are the goals of separating waste, and the last goal mainly depends on recycling activities.

Table 3.3 - List of Waste management goals at Leiden University from 2016 to 2020

No.	Goal	Responsible for initiation	When
WAS1	The external communication of the Administration & Central Services Department (BB) will be 95% digital, reducing its paper use by 40% compared with 2015.	Administration & Central Services	2017
WAS2	Each year the amount of waste per Leiden University student will be reduced, to a maximum of 25 kilos per student in 2020.	HSE	2020
WAS3	The amount of incinerated commercial waste will be less than 250 tons in 2020.	HSE	2020
WAS4	Collection points for plastic, paper, and commercial waste will be installed in all University buildings (50 people or more).	HSE	2017
WAS5	From 2017, items that the University no longer needs will be offered to staff and students via a webshop.	HSE	2017

Source: prepared by the author based on Environmental Policy Plan 2016-2020 (LU, 2016)

- Organizing. All faculties and central services are involved in implementing the Environmental Policy Plan 2016-2020, which specifies the different responsibilities of departments and specialist centers for achieving individual goals. As for the goals in education and research, the responsibility for implementation lies mainly with the faculties and lecturers. The goals in the area of university operations will be achieved under the leadership of the Administration & Central Services Department and the expertise centers, in particular the Real Estate Directorate, the University Services Department, and the Health, Safety & Environment Department (HSE). Eight departments are participating in the general plan, see Figure 3.1. In the cloud map, the size of the keyword font represents the frequency of occurrence. That is, the department with larger font takes on more responsibility in practice. In terms of education and research, HSE and Administration & Central Services are responsible for the initiation of the related activities, especially the HSE.

Figure 3.1 - Departments involved in the Environmental Policy Plan 2016-2020

Source: prepared by the author

It is essential to mention that the Green Office is responsible for coordinating and initiating the dynamic transition process of all available resources on campus towards SD in Leiden University, which was established by the HSE in 2016. The Green Office is committed to ensuring that Leiden University becomes more sustainable on all fronts, and advancing waste separation management is one of its tasks. Indeed, the Green Office movement began in 2010 as an experiment at Maastricht University, and since then it has grown into an international movement involving large numbers of students and staff. The Green Office model initiated by RootAbility exists in six principles, including an operational team composed of students and staff, the official mandate, resources for project implementation, integration with the organizational structure, collaboration with internal and external stakeholders, and professional competence training for members. The Green Office is part of the Administrative and central services of Leiden University and can be supported by the relevant internal management and the dedicated advisory committee. Its main objective is to achieve structural sustainability in Leiden University's education, research, and facilities, and foster a culture of sustainability on campus to make the university more sustainable.

- Leading. To achieve the goals of waste management, Leiden University has adopted a series of publicity and education activities and incentive measures for the campus units and all teachers and students. In terms of publicity and education, Leiden University has been working to raise awareness of environmental policies and measures among staff, students, and external stakeholders through communication activities. Communication takes place digitally through websites, social media, e-mail, blogs and vlogs, videos, apps, and narrowcasting. The Sustainable University is a separate archive on the university's website that maximizes access to environmental policy. In addition, the Green Office sets out Green Paper on how universities can play a meaningful role in protecting a sustainable world through education, research, social impact, and their operations. Generally, the Green Paper is usually given away free to teachers, administrators, participating organizations, and interested residents.

In terms of specific activity implementation, Leiden University carries out many concrete activities in practice to ensure the performance of the three spearheads that include preventing waste, separating waste, and recycling in limiting the amount of waste. Concerning waste prevention, Leiden University has undertaken an active campaign to reduce paper use in Administrative & Central Services and expects to gain experience for application to other departments. In fact, except for marketing and external communications, especially for student recruitment, where paper is still needed to produce brochures, internal communication in the campus's administrative offices is almost entirely via e-mail, websites, and social media to minimize paper use. Also, Leiden University regularly organizes activities to advise staff and students on how to prevent waste and to encourage them to participate in waste reduction initiatives.

As for the spearheads of separating waste and recycling, Leiden University pursues more refined waste separation to limit the amount of waste, that is, to achieve maximum separation at source for better recycling efficiency and effectiveness. Since 2019, Leiden University has further refined the waste separation work to optimize the waste streams with the formation of five major waste streams, including paper and cardboard waste, organic waste and food waste, plastic packaging, metal and drinking cartons (PMD), coffee cups, and residual waste. By collecting coffee cups separately, the PMD stream is no longer contaminated, thus ensuring the desired purity. Meanwhile, there are some other separate waste streams collected on campus, such as wood, construction waste, glass, confidential documents, batteries, printer cartridges, and mobile phones. They are not a major waste stream, but these are also important factors in the recycling of reusable resources on campus. In addition to the residual waste cannot be recycled, the rest of the waste streams are ultimately directed to the recycling of separating resources. A recycling webshop has been set up to provide staff and students with second-hand commodities to promote reuse and reduce waste disposal costs. Also, Leiden University made deserted furniture available to student societies through the Green Office in 2020.

- Controlling. Waste management at Leiden University complies with the provisions of the Environmental Management Act, the Environmental Permit, the Activities Act, and the National Waste Management Plan. In this case, the fundamental principle of Lansink’s ladder is applied in the waste management program at Leiden University, which was put forward by the Dutch politician Ad Lansink in 1979. Lansink’s ladder principle was elevated to Dutch environmental law in 1994 and later adopted by the European Union in the 2008 Waste Framework Directive (Gharfalkar et al., 2015). The priority of waste disposal has been stipulated in this acknowledged standard for waste management, namely prevention, preparing for reuse, recycling, recovery, and disposal, see Figure 3.2.

Figure 3.2 - Waste hierarchy in the European Commission

Source: prepared by the author based on the official website data and information

According to this waste hierarchy, preventing waste generation is the best choice, while landfilling is the last resort when the current treatment methods are not appropriate. All waste must be sorted unless it is unreasonable.

It is naturally crucial to achieving these goals in the Environmental Policy Plan 2016-2020 in a transparent and structured manner. In this context, the administrative office of Leiden University is responsible for monitoring the plan implementation and maintaining contact with the relevant centers of expertise, and coordinating activities. Also, the HSE is responsible for implementing the overall environmental policy plan. The primary way to make information available is through the Green Office website and the separate dossier named the sustainable university on the university's new website. The electronic version of the Sustainability Report (LU, 2020) is the most direct presentation of Leiden University's progress in SD, including specific activities and projects in the areas of sustainable housing, energy, water, and the achievement of goals. The advancement in the waste management program is clearly shown in the Leiden University Sustainability Report 2020, as shown in Table 3.4. Some of the goals were not fully achieved due to the COVID-19 pandemic and the adjustment of relevant responsible departments. Still, the courage to disclose the data and admit its shortcomings also shows Leiden University's determination to strive for SD.

Table 3.4 - State of the waste management goals in the Environmental Policy Plan 2016-2020

Goals	Status	Responsible	When
WAS1	Not	Administrative Office	2017
WAS2	Realized	University Facilities Company	2019
WAS3	Not	University Facilities Company	--
WAS4	Realized	University Facilities Company & Faculty of Mathematics and Natural Sciences	2017
WAS5	Ongoing	Health, Safety and Environment Department	Since 2019

Source: prepared by the author based on the Sustainability Report (LU, 2020)

Analysis of the current situation at H University. The establishment of a waste separation management system is a systematic project, involving planning, policy, organization, infrastructure, technology, supervision, and other aspects of work. With the promulgation of national and local waste separation management regulations in China, waste separation in universities is no longer a problem of policy and technology, but an issue of management. Therefore, to facilitate the progress of the waste management program in the Green Campus Initiative in China, it is necessary to analyze the difficulties existing in waste management in universities from the perspective of management. This study selects H University as the object, which is at a medium level of education and development scale nationally and representative to conduct a case study.

H university locates in the Xinxiang City of Henan Province, which is a provincial general undergraduate university. Its educational and development scale is in the middle level among universities in China, so it is representative to select it for a case study. The campus of H university covers an area of 165.2 ha, with a total floor area of 620,000 square meters, including the Xinxiang campus (undergraduate level) and Huixian campus (junior college level). There are 21 teaching faculties, among which the AI faculty was just established in 2020. Also, there are 1759 staff members and 29130 full-time students, including 24202 undergraduates and postgraduates in total on the Xinxiang campus and 4928 junior college students on the Huixian campus. The main areas on the campus of H university include teaching areas (12 teaching buildings and two laboratory buildings), residential areas (14 student hostels and 41 teacher apartments), dining areas (five restaurants), public office areas (one administrative office building and two libraries), and affiliated school (one primary school and one kindergarten). In this study, the Xinxiang campus is focused on as the object of investigation on the status quo of waste separation management. The investigation period is from May to June 2021.

- Estimation of waste generation on campus. From the perspective of the waste stream, waste separation management involves the process of dumping, collection, sorting, transfer, and disposal after the waste generation. However, as a small unit in the social system, universities do not have the conditions and capacity to manage the entire waste streams of all types from generation to final disposal. Generally, campus waste is transferred by specialized outsourcing waste transportation companies to transfer stations designated by the local government for unified disposal after separated collection and sorting on campus, such as reusing, remanufacturing, landfill, or incineration. Only a small part of the waste can be disposed of on campus in some universities, such as the direct donation of old clothes and the fermentation of garden waste for fertilizer. Therefore, to be precise, the current waste separation management in universities mainly involves the dumping, collection, and sorting processes.

After confirming with the waste transportation company at H University, there are four waste trucks arranged for the removal of the campus waste four times every day, that is, a total of 16 trucks of waste are cleared out every day, each weighing about 650kg. To estimate the daily waste output per capita, this study calculated the total population according to the number of permanent residents on campus, which is the sum of the number of full-time students on the Xinxiang Campus (24,202) and the number of resident staff and their families (2,338), see Table 3.5.

Table 3.5 - Estimation parameters of waste output at H University

Number of waste trucks	Number of clearances per vehicle per day	Vehicle load (kg)	Number of permanent residents on campus	Daily waste output (kg)	Per capita daily output (kg)
4	4	650	26540	10400	0.39

Source: prepared by the author

The calculations are based on the daily waste output while the students are learning in school, not the data when students are absent during summer and winter vacations. If this study considers the situation that the students spend 273 days in school excluding summer and winter vacations according to the university calendar, the average annual output per student is about 90.2kg. To understand the difference with foreign universities, this study selected some universities in the Netherlands for comparison.

The calculations are based on the daily waste output while the students are learning in school, not the data when students are absent during summer and winter vacations. So, it is very intuitive to compare with other Chinese universities using similar calculation methods. Different from Chinese universities, Netherlandish universities mostly use annual waste output per capita as an indicator. If this study considers the situation that the students spend 273 days in school excluding summer and winter vacations according to the university calendar, the average annual output per student at H University is about 90.2kg. The annual waste output per capita at H University is relatively low compared with some other Chinese universities but far exceeds that of universities in the Netherlands, see Table 3.6.

Table 3.6 - The per capita waste output of some universities

Colleges and universities	Waste output per capita (kg)		Country
H University	0.39(per day)	90 (per year)	China
Nanjing Agricultural University	0.873 (per day)	--	China
Nanchang University	0.428 (per day)	--	China
Zhejiang Sci-Tech University	1.5 (per day)	--	China
China West Normal University	0.4 (per day)	--	China
Leiden University	--	31 (per year)	Netherlands
Utrecht University	--	55 (per year)	Netherlands
University of Groningen	--	29 (per year)	Netherlands
University of Amsterdam	--	29 (per year)	Netherlands

Source: prepared by the author based on the environmental coordinators of the universities concerned and the university website

- Situation of waste management at H University. Although relevant national policy documents have stipulated that colleges and universities should set up specific waste management goals, specialized management organizations, incentive mechanisms, and safeguard measures, H University has not taken enough visible actions in these aspects for the time being. The property management division under the Logistics Management Department is mainly responsible for waste management at H University. There is not yet a particular organization to implement the waste management program and mobilize all faculty units and teachers and students to participate in waste separation recycling. In the current waste management model, there are many problems in the measures of waste separation.

First of all, the waste separation standards between universities and cities are inconsistent, which could inevitably affect the effect and efficiency of waste management. University is a special kind of community, so the waste sources on campus are similar to the origins of municipal solid waste. The direction of the waste streams on campus is bound to relate to the municipal waste treatment process. With the in-depth advancement of waste separation management in China, waste separation standards have also been unified and clearer. In China's national standard Signs for Classification of Municipal Solid Waste (GB-T19905-2019) that was implemented in 2019, there are four major categories and 11 sub-categories of waste separation that are clearly defined in the stipulation, including Recyclable Waste (paper, plastic, metal, glass, and textiles), Hazardous Waste (tubes, household chemicals, and batteries), Food Waste (Household food waste, restaurant food waste, and other food waste), and Residual Waste. This waste separation standard is generally applicable to the whole process of classified dumping, collection, sorting, transportation, and treatment of domestic waste throughout China. However, the current waste separation system in many colleges and universities has different characteristics and is not uniformly classified in accordance with national standards. At present, the waste separation standard at H University is still following the traditional dichotomy of recyclable waste and non-recyclable waste. Recyclable waste contains six sub-categories, including newspapers, glass cans, plastic, computers, pop cans, and clothes. Similarly, the six sub-categories of non-recyclable waste are contaminated paper, cigarette butts, pet droppings, broken ceramics, large bones, and disposable tableware.

Moreover, through a random selection of trash cans in different functional areas for inspection, this study found that the correct separation of the waste on campus is insufficient. It is common to use trash bags to mix all the waste and dump them in the trash bins. Actually, this phenomenon also exists to a certain extent in many Chinese universities (Liu et al., 2014; Liu et al., 2021; Zhu, 2012).

It is mainly due to the lack of attention to waste separation in campus management, which is reflected in the outdated waste separation facilities that cannot meet the requirements of the new standards, as well as the shortage of education and guidance for students' behaviors.

Besides, the inadequate development of municipal waste separation systems is a considerable reason for this problem. Under the existing system, the designated waste collection company at H University has always adopted a mixed collection and transportation method to transport the campus waste to the transfer station for unified separation. Mixed collection and transportation not only mean that the categorization in the dumping process is meaningless but also leads to more serious secondary pollution, resulting in the reduction of the recycling rate and the increase of labor costs.

It is admitted that the efforts of waste separation on campus are ineffective under the existing waste separation recycling model. The waste streams collected on campus reveal that H University only acts as an intermediary coordinator in waste separation management to transfer waste management services to other enterprises through contract outsourcing, see Figure 3.3. As a matter of fact, universities should take more responsibility for waste separation management as administrators and leaders of SD on campus.

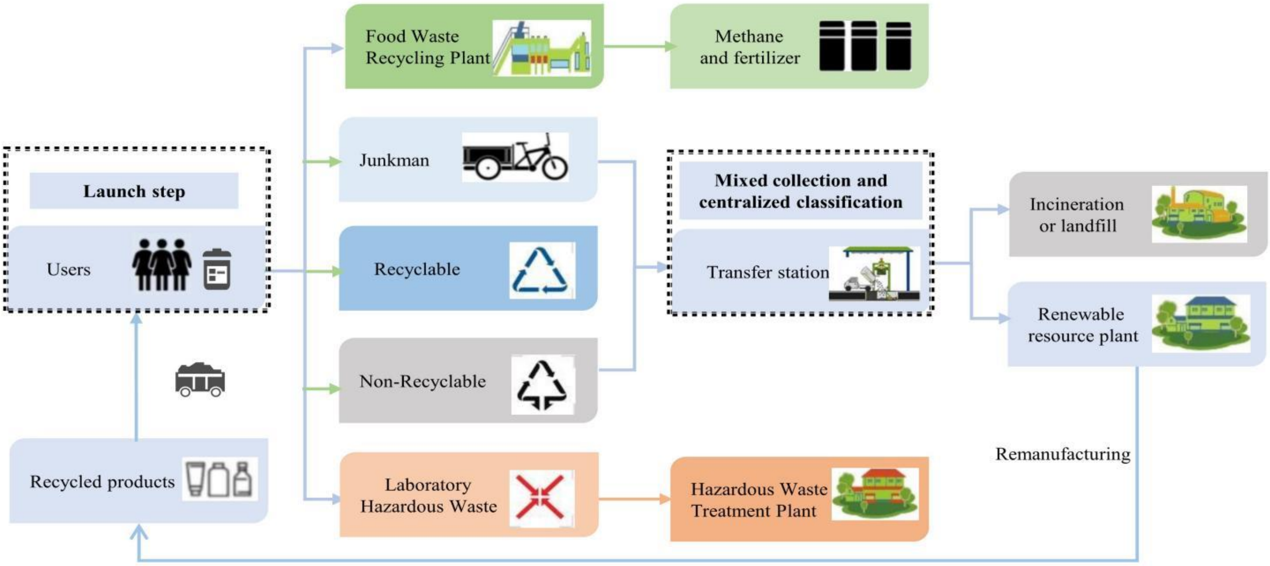

Figure 3.3 - Waste streams collected at H University

Source: prepared by the author

On a positive note, the kitchen waste in campus restaurants is uniformly recycled by the company designated by the urban market supervision department for biological fermentation treatment. The hazardous waste produced by the laboratories is also disposed of by a particular outsourcing company designated by H University. In addition, campus junkmen have contributed to waste separation recycling to a certain extent, admittedly, although they have brought inconvenience to campus management. They mainly collect uncontaminated cardboard, plastic bottles, books, and other highly remunerative waste to resell it to waste transfer stations, which protects the value of some recyclable materials and avoids material contamination caused by mixed collection.

Optimization strategy of waste management program for H University. waste separation recycling on campus is the leading way for universities to contribute to waste reduction and resource recovery. To get rid of the complex predicament of waste separation on campus, the construction of the waste separation management system is particularly significant. Universities that have pioneered and developed waste separation management systems could provide enlightenment for the universities that are about to take relevant action. Therefore, H University should take inspiration from Leiden University’s model in implementing the waste management program on campus.

Firstly, H University could accomplish top-level design to put a waste management program into the CE framework and green campus system. The overall planning and scheme formulation of the waste management program should involve all departments and all university personnel. On the one hand, H University should explore the establishment and improvement of waste separation regulations, and standardize the whole process of waste stream on campus, including waste category definition, separated dumping, separated collection, separated transportation, and separated treatment. Also, it is necessary to straighten out the responsibilities and obligations of staff and students in campus waste separation. On the other hand, H universities should carry out regional governance according to different functional areas on campus. On the premise of overall planning, appropriate fine-tuning can be carried out based on the actual situation to improve the campus waste separation program continuously. Meanwhile, it is necessary to set up corresponding authority and responsibility institutions and relevant responsible persons at H University to achieve the goal of the waste management program. The organizational mechanism should be an organizational structure with different levels from top to bottom to promote all units and stakeholders in universities to participate in waste separation recycling activities.

Furthermore, university staff and students are the primary consumers and users of resources on campus. If they are unaware of the significance of waste separation recycling and the measures that have been implemented on campus, it will directly lead to the demise of the university waste management program. Therefore, H University should popularize the knowledge and value of waste separation widely through publicity and education, and gather the executive power of waste separation from the public. The advantages of teaching resources in colleges and universities could be exerted to integrate the waste management program into the construction of university spirit, teaching spirit, and learning spirit by taking advantage of the curriculum instruction and extra-curricular education. Also, H University should carry out different forms of waste separation publicity and education activities according to different groups to gradually cultivate awareness and behavior. It should be used to explore the establishment of an intelligent waste separation applet could be established based on the campus’s new media platform to assist waste separation management. Besides, the completeness of waste separation facilities directly determines the process of waste separation. H University should improve the waste separation facility and infrastructure in combination with the overall plan for waste separation management. Also, it is essential to arrange the waste dumping points and cleaning frequency according to different regions so that waste bins be cleaned up timely to avoid polluting the campus environment and improve the efficiency of waste removal (Qiu et al., 2019).

Finally, it is necessary to expand public participation in waste separation on campus to stimulate the internal power of waste separation by establishing appropriate reward and punishment mechanisms and supervision mechanisms. Both education and coercion are indispensable. The majority of staff and students should recognize the benefits and rewards of waste separation, and also realize the penalty for not carrying out waste separation activities. If waste separation behaviors could bring not only intrinsic motivation such as pleasure but also external motivation such as respect and praise from others and material reward, people's initiative will be naturally strengthened. Meanwhile, different forms of punishment for not classifying waste or failing to classify waste correctly can also produce adverse reinforcement effects. Supervision mechanisms are indispensable to the implementation of the waste management program on campus. H University should disclose the waste management work plan, relevant activities, and target realization both inside and outside the university in accordance with regulations, and consciously accept the supervision of staff and students inside the university, as well as all walks of life in society.

To accomplish waste management rather than just staying at the theoretical level, this study puts forward a specific waste management program at H University to promote the implementation of waste separation recycling on campus.

WASTE MANAGEMENT PROGRAM AT H UNIVERSITY

1. Introduction

1.1 Purpose and Background

H University Logistics Management Department has developed this Program to establish standard procedures for the management of wastes generated on campus in accordance with all local and national regulations. These regulations include but are not limited to government laws and university stipulations. The purpose of this Program is to protect human health, the environment, and depleting resources by preventing the release of contaminants through sound, best management practices for waste generation, handling, and disposal.

1.2 Scope

This Program applies to all permanent residents and migrants of H University that include but not limited to the students, faculty, staff, management, and campus visitors.

The waste in this Program refers to all kinds of surplus material generated by the H University community in any activity on campus, which includes but is not limited to laboratory research, maintenance, site maintenance, academic instruction, and restaurant service. waste separation on campus is consistent with the national standards (GB/T 19095-2019), including four categories and 11 sub-categories.

1.3 Principles

The aim of waste management is to maximum improve the recycling efficiency of reusable resources and minimum reduce the quantity of waste going to landfills following waste hierarchy management. Waste must be treated as a resource and the only waste that should be sent to landfill is the ultimate waste that cannot be reused, recycled, or composted. Waste management follows mainly the 3R principle (Reduce, Reuse, Recycle), in which Reduce is the top priority in waste disposal.

- Reduce: where applicable, H University should endeavor to reduce the consumption of materials that generate waste;
- Reuse: where necessary, H University should redistribute surplus materials within the community for reuse;
- Recycle: where necessary, H University should aim at recovering materials that are no longer usable.

2. Organization and responsibility

To strengthen scientific management in waste separation, the campus waste separation management leading group has been established as the routine proceeding organ, with the university rector as the leader, the vice-rectors who are in charge of administrative work, comprehensive management, student work, personnel work, and logistics work as the deputy leader, and the prominent leaders of Logistics Management Department and secondary faculties as members. The specific work is mainly responsible for various specialized offices or groups under it, including unifying and standardizing the campus waste separation management and mobilizing the functional departments, teachers, and students to participate in the waste separation recycling actively, see Figure 3.4.

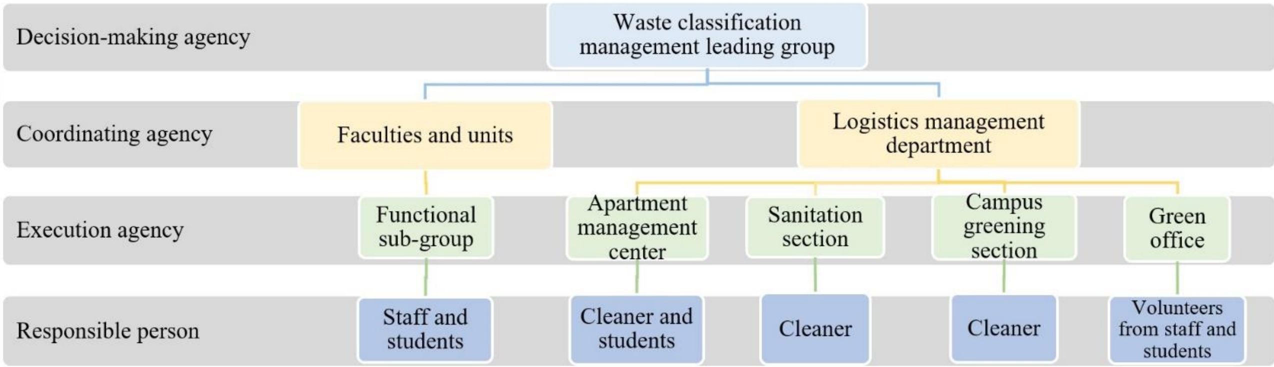

Figure 3.4 - Organization structure of waste separation management at H University

Source: prepared by the author

2.1. H University waste separation management leading group is responsible for:

- Formulating policies for waste separation management;
- Making overall planning and scheme of the Waste Management Program;
- Evaluating and developing the Waste Management Program;
- Forming and reporting on the annual performance of campus waste management;
- Raising funds for Waste Management Program.

2.2. Logistics Management Departments are responsible for:

- Promoting the implementation of the Waste Management Program on campus;
- Providing annual training and/or technical guidance on waste management requirements and procedures to all affected employees;
- Maintaining waste contracts with all the waste recycling and transport

companies;

- Facilitating waste minimization efforts with adequate and practical manners;
- Taking effective measures to involve all teachers, students, and staff actively participate in waste separation activities;

2.3. Sub-group and relevant sections are responsible for:

- Ensuring employees and students are properly instructed in the requirements of this program;
- Ensuring standard operating procedures based on this Program are developed for waste management, waste minimization, and handling emergencies;
- Ensuring that all employees who handle waste receive initial waste management training in waste management procedures as well as annual refresher training if required by this Program;
- Ensuring employees and students who fail to follow the Program are retrained and educated;
- Enforcing Program requirements within their areas of responsibility.

2.4. Employees and students are responsible for:

- Learning and following Waste Management Program requirements for comprehensive waste management;
- Participating in training and education in waste separation and disposal;
- Assuming personal responsibility for compliant identification, storage, dumping, and disposal of all wastes generated as a result of his or her activities;
- Developing and implementing waste reduction measures whenever feasible.

3. Ambitions and implementation

H University will take a three-pronged approach to waste reduction within the priorities, which includes preventing waste generation, strengthening front-end waste separation, and improving back-end recycling. The Logistics Management Department and various faculties will develop the following list of orientations within the next five years through cooperation with all units at H University.

3.1 Orientation of preventing waste

- Replacing paper for office and meeting documents with electronic files in administrative departments;
- Replacing the paper and pen examination with computer examination for students in some appropriate subjects to reduce plenty of paper waste;
- Promoting reusable cups and cutlery instead of disposable tableware;
- Encouraging the donation of used clothing to reduce the amount of waste;
- Advocating buying meals on demand at restaurants to avoid food waste;
- Offering elective courses related to waste management or resource recycling;
- Integrating the idle bicycles on campus to construct a shared cycling system;
- Constructing an internet second-hand book trading platform.

3.2 Orientation of front-end waste separation

- Replacing the outdated waste collection facilities with those in line with unified national standards;
- Allocating appropriate separation trash bins reasonably according to the different functional areas on campus that generate different categories of waste;
- Collecting some particular categories of waste, such as cardboard and plastic bottles, in dedicated waste streams to increase the recovery efficiency;
- Organizing waste separation knowledge contests and/or speech competitions to promote the knowledge of waste separation;
- Setting up particular work-study positions for students to guide and supervise waste separation;
- Encouraging students to set up organizations and associations for promoting waste separation on campus;
- Evaluating and rewarding excellent individuals and units in waste

separation.

- Cooperating with on-campus businesses to encouraging waste separation behaviors with discounts on their mobile phone bills or benefit rewards in the nearby convenience store.

3.3 Orientation of back-end waste recycling

- Pulverizing the garden waste and making it into fertilizer by fermentation;
- Making the food waste into organic fertilizer by fermentation;
- Setting up a semi-closed waste separation transfer center on campus for carrying out secondary separation to avoid mixed collection;
- Cooperating with qualified resource utilization and terminal disposal enterprises to take harmless treatment for wastes that cannot be realized recovery on campus.

4. Supervision and guarantees

During the implementation of this Program, H University will exercise the following supervisory measures to guarantee the performance of waste management.

- Announcing the waste management work plan and overall schedule on the university website;
- Presenting the annual report on waste management that includes the actions taken and goals achieved to accept the supervision of staff and students, as well as all walks of life in society;
- Incorporating the progress of waste management programs in all faculties and departments into the annual assessment.

3.2 Questionnaire survey of students' waste separation attitude and behavior

Just as the waste sorting plan of the society needs the support and cooperation of all residents, the waste management program of colleges and universities as a large community also needs the support and participation of residents. College students are the most important part of college community residents, and their attitude and participation in campus waste separation are the key factors for the successful implementation of college waste management projects. Therefore, it is necessary to investigate the attitudes and behaviors of college students towards waste separation.

Preparation and implementation of questionnaire survey. The methodology followed by this survey is shown in Figure 3.5.

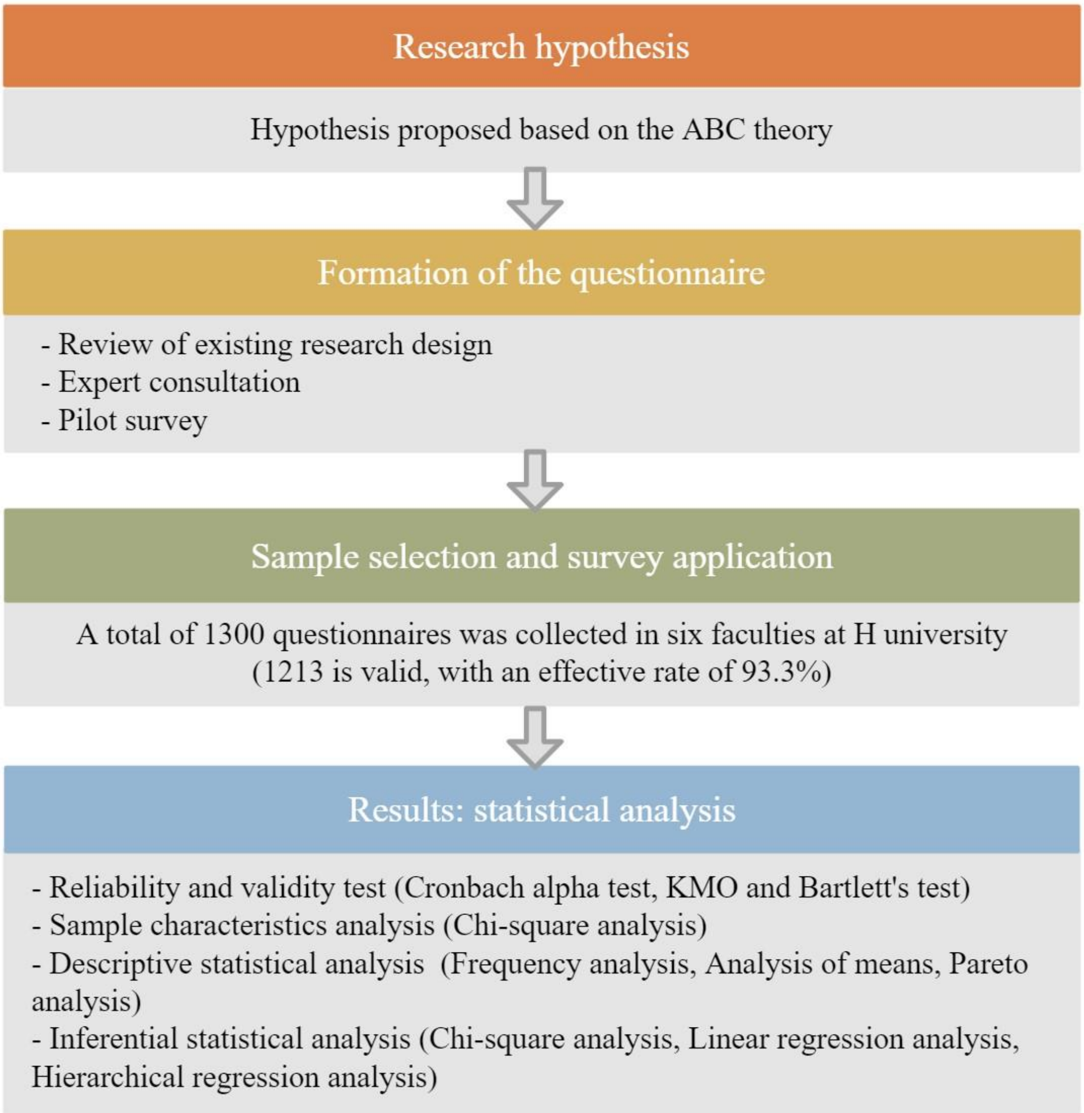

Figure 3.5 - Methodology followed in this survey

Source: prepared by the author

First, through the review of the previous studies focused on student attitude and waste separation behaviors, the research hypotheses were put forwards. Second, a questionnaire was compiled with the consideration of the existing research design. Third, a representative sample was selected from several faculties at the Henan Institute of Science and Technology in China. Finally, the results obtained were statistically analyzed with various methods

- Research hypothesis. According to the ABC theory (attitude-behavior-context), environmental Behavior (B) is generated by the interaction of individuals' Attitude variable (A) and Context factors (C) towards environmental protection (Guagnano et al., 1995). Previous studies have also confirmed that there is a significant positive correlation between individuals' environmental attitudes and their participation in environmental behaviors (Brent, 1996), and the public's environmental attitudinal behavior path is affected by context factors, that is, context factors have a positive or negative regulating effect on environmental attitudinal behavior path, and will promote or inhibit environmental behavior accordingly (Wang, 2013).

In addition, the review of relevant studies on the attitude and behavior of waste separation shows that there are few studies on the attitude and behavior of waste separation in China, especially the lack of direct evidence on whether the variable relationship in the ABC model applies to college students. In addition, the characteristics, status, and environment of college students are different, and the moderating effects of external context variables are different from those of the general public. Therefore, this study verifies the variable relationship, influence path, and regulating factors of college students' waste separation attitude and behavior.

Based on ABC theory and previous research results, this study this study develops a conceptual framework to provide an interpretation of the expected relationship between the variables. It is expected that college students' waste separation attitude (independent variable) has a direct impact on their waste separation behavior (dependent variable). For example, positive attitudes towards waste separation can have a beneficial effect on the actual occurrence of waste separation behavior. Besides, this study expect that the internal and external contextual factors (moderating variables) have a moderating effect on the relationship between attitude and behavior. Hence, the following hypotheses are formulated to be examined in this research:

Hypothesis 1: Students' attitudes toward waste separation directly impact their waste separation behavior.

Hypothesis 2: Students' internal contextual factors can moderate the attitude-behavior pathway of waste separation.

Hypothesis 3: External contextual factors on campus can moderate the pathway of attitude-behavior influence on waste separation.

- Formation and the structure of the questionnaire. The purpose of this survey is to understand the attitude and behavior habits of H university students towards household waste separation and recycling. Therefore, a questionnaire was prepared to ground on the research design of Stern et al. (1999) and Fu et al. (2015) and then adjusted according to the cultural background and behavior situation of college students. In addition, interviews were conducted with some experts and representative students to understand the main factors contained in various variables and finally form the original questionnaire.

In order to build a formal questionnaire that meets the research needs, the original questionnaire was trial-tested on a small scale before the formal survey and was repeatedly modified and adjusted according to the results of the item analysis and internal consistency testing. The Likert scale scoring method was adopted in the questionnaire, in which the points ranging from 1 to 5 represent the direction of respondents' attitudes and behaviors. The lowest score (score 1) indicates that respondents have a relatively negative attitude or behavior toward waste separation. On the contrary, the highest score (score 5) indicates that respondents are temporarily inert in attitude or behaviors toward waste separation.

- Sample selection and survey application. There are a total of 24,202 full-time college students in the Xinxiang Campus of H University. In view of this large overall sample size, this study calculated the size of the sample to be selected based on the sample content estimation method proposed by Uchida (2007) with the following formula:

$$n \geq \left(\frac{k^2}{\alpha^2}\right) p(1-p) \qquad (3.1)$$

where *n* represents the sample size, *б* stands for the margin of error or confidence interval (*б* = 5%), *k* is the selected alpha level in normal typified distribution (*k* = 1.96), and *p* is the percentage of respondents who selected a specific choice (*p* = 0.5). After calculation, this study obtained *n* = 384.

Due to the COVID-19 pandemic, the school was suspended during the investigation period, and students were taking online classes at home. Therefore, the questionnaire was distributed, filled in, and recovered through the network platform. To improve the reliability of the survey results, this study expanded the sample as much as possible. In the survey, questionnaires were distributed to 1380 students from six faculties, of which a total of 1300 respondents made responses, with a recovery rate of 94.2%. Among the collected questionnaires, 1213 were valid, representing an effective rate of 93.3%. It is worthwhile highlighting that the representative sample size of 1213 is much larger than the 384-sample size required according to the calculation result.

- Statistical Analysis Method. Statistical analysis software SPSS 23.0 was used for the statistical processing of data at different levels. Statistical processing of data at different levels is required.

First, a statistical analysis of the socioeconomic characteristics of the sample was carried out. Second, descriptive statistics are carried out on the results of each item involved in the questionnaire. Finally, based on descriptive analysis, inference statistics are carried out on the attitudes, behaviors, and situations of college students towards waste separation and recycling, so as to verify the proposed hypothesis.

On the one hand, it is necessary to analyze the different relationships between the attitude and behavior of waste sorting and recycling among the classified people.

That is, by combining socioeconomic variables with the responses to the scale questions, this study can understand the differences in attitudes and behaviors of different types of groups in waste sorting and recycling. On the other hand, it is necessary to analyze the influence of college students' attitudes towards waste sorting and recycling on the corresponding behavior. Furthermore, it is necessary to analyze the moderating effect of context factor variables on the attitude-behavior influence path.

- Reliability and validity test. The Internal Reliability index Cronbach's alpha value was used to test the scale Reliability in the questionnaire. The questionnaire contains 16 scale items, involving the attitude variable (five items), behavior variable (four items), internal context variable (three items), and external context variable (four items). A contradictory item was set in the items of the attitude variable, which was only intended for censoring invalid questionnaires and not for statistical analysis. As shown in Table 3.7, Cronbach's α value of the scale was 0.866(>0.8), indicating that the scale had good reliability and could be used for further analysis.

Table 3.7 - The reliability and validity test of the scale

Items	Sample size	Cronbach alpha coefficient	KMO	Bartlett Test of Sphericity	Degrees of freedom (df)	*p* value
16	1213	0.866	0.880	10473.071	120	0.000**

** p < 0.05, * *p < 0.01*

Source: prepared by the author

In order to test content validity, the expert judgment method was used. First, the original questionnaire was built based on an interview with some experts in the field and representative students. Before the formal test, the original questionnaire was used to conduct a preliminary survey for further modification to meet the research needs. Second, the factor analysis method was used to test the construct validity, which is usually achieved by the KMO value and Bartlett's test of sphericity. Test results showed that the questionnaire was valid, indicating the research data is reliable for extracting information.

Sample characteristic analysis. Through the analysis of the socio-economic characteristics of the respondents, it is found that the share of females from the respondents is higher than that of males, the group aged 18-20 accounts for the largest proportion of the sample (66.03%), and the number of freshmen participating in the survey is the largest (42.54%)

The result reflects that females and lower-grade students have higher enthusiasm and willingness to participate, which is consistent with the actual context. The respondents met the quota sample control target of the study. A Chi-square test (cross-analysis) was carried out for the gender, age, and grade of the respondents. It was found that there was no significant difference in gender in different age stages and grades in the selected respondents (p >0.05), as shown in Table 3.8.

Table 3.8 - Chi-square analysis between socioeconomic characteristics

Items	Categories	Gender		Total	χ squared	*p*
		male	female			
Age	<18	3.49%	3.05%	3.22%	6.034	0.110
	18-20	62.31%	68.30%	66.03%		
	21-23	33.12%	28.25%	30.09%		
	≥24	1.09%	0.40%	0.66%		
Grade	Freshman	43.14%	42.18%	42.54%	5.460	0.141
	Sophomore	26.80%	25.60%	26.05%		
	Junior	21.35%	19.23%	20.03%		
	Senior	8.71%	13.00%	11.38%		
A total of		459 (37.84%)	754 (62.16%)	1213		

* $p < 0.05$, * *$p < 0.01$

Source: prepared by the author

Descriptive analysis. To facilitate the analysis of the relationship between each pair of variables, it is necessary to generate new variables by combing the factors contained in each variable into a whole. In this study, exploratory factor analysis was performed to determine the weights of each factor in each variable. The results of all KMO and Bartlett's tests indicated that the data were appropriate for factor analysis. The titles and weights of the factors are presented in Table 3.9. Correlation analysis was conducted on the factors involved in attitude, behavior, and context variables, and the results showed that there was a positive correlation between the factors of each variable. The weighted summation method was employed for the factors of each variable to generate new variables X (attitude), Y (behavior), Z1 (internal contextual factors), and Z2 (external contextual factors).

Table 3.9 - Titles and weights of the factors of each variable

Variables	Titles and Weights of the Factors				Formulas
X (attitude)	X1 (value)	X2 (awareness)	X3 (knowledge)	X4 (responsibility)	X = 0.2799 × X1 + 0.3046 × X2 + 0.1422 × X3 + 0.2733 × X4
	27.99%	30.46%	14.22%	27.33%	
Y (behavior)	Y1 (publicity and promotion)	Y2 (waste separation and recovery)	Y3 (waste textiles recovery)	Y4 (express package recovery)	Y = 0.2350 × Y1 + 0.2592 × Y2 + 0.2684 × Y3 + 0.2374 × Y4
	23.50%	25.92%	26.84%	23.74%	
Z1 (internal contextual factors)	Z1.1 (recognition and material incentives)	Z1.2 (credit or scholarship incentives)	Z1.3 (incentives in further education or employment)	--	Z1 = 0.3186 × Z1.1 + 0.3427 × Z1.2 + 0.3387 × Z1.3
	31.86%	34.27%	33.87%	--	
Z2 (external contextual factors)	Z2.1 (infrastructure construction)	Z2.2 (mission and curriculum)	Z2.3 (regulations and rules)	Z2.4 (culture and atmosphere)	Z2 = 0.2442 × Z2.1 + 0.2452 × Z2.2 + 0.2558 × Z2.3 + 0.2548 × Z2.4
	24.42%	24.52%	25.58%	25.48%	

Source: prepared by the author

- Presentation of scale scores and mean value of each variable. Figure 3.6 displays the visual representation of each factor on the five-point Likert scale. In general, the respondents' attitudes and behaviors toward waste separation are mostly positive. Specifically, the respondents showed the strongest consistency on the X4, while the lowest overall consistency was found for the X3.

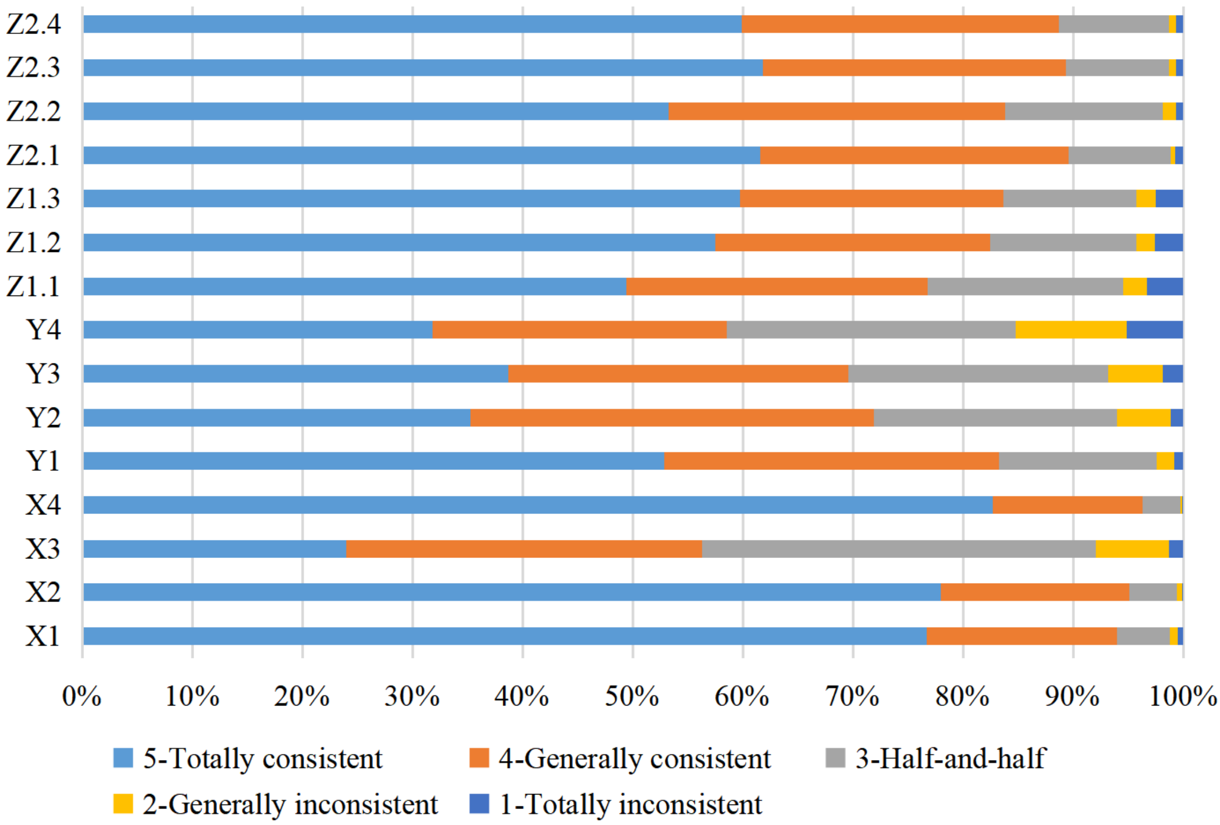

Figure 3.6 - Respondents' responses on different variables

Source: prepared by the author

The variable of college students' attitude towards waste separation mainly includes the value (X1), awareness (X2), knowledge (X3), and responsibility (X4) factors. As shown in Figure 3.7, the overall mean value on the attitude scale was 4.59, indicating that the attitude of the respondents towards waste separation is relatively positive. The mean values of each factor from high to low are X4 > X2 > X1 > X3. This result reflects that college students are generally aware of the importance of waste separation and their responsibility in realizing waste separation and recovery but do not have adequate knowledge about waste separation. This indicates that the attitudes of college students toward waste separation are only at the level of consciousness without learning the relevant knowledge of waste classification, so it is not enough to deal with the practical problems of waste separation and recovery.

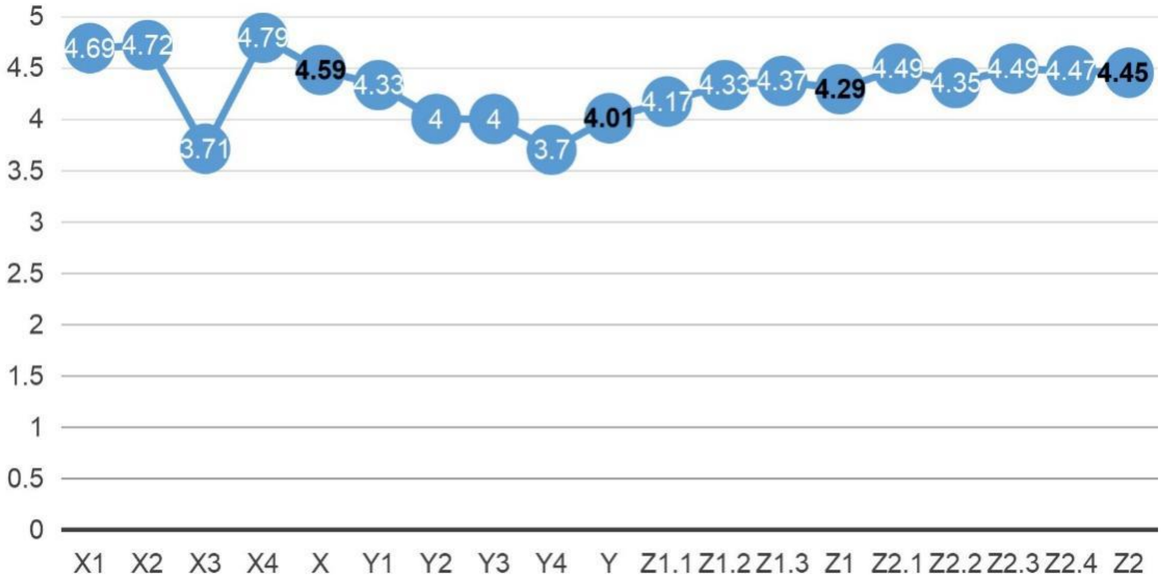

Figure 3.7 - Comparison of the mean values of different variables

Source: prepared by the author

The behavioral variables of waste separation of college students mainly include publicity and promotion (Y1), waste separation and recovery (Y2), waste textiles recovery (Y3), and express package recovery (Y4). Statistical results of various factors in behavioral variables are also shown in Figure 3.7. The mean value of various factors from high to low is Y1 > Y2 = Y3 > Y4. This result reflects that college students are generally able to participate in the promotion activities of waste separation but are ineffective in their waste separation behavior.

The context variables of waste separation of college students mainly include internal contextual factors (Z1) and external contextual factors (Z2). The former contains three factors, namely recognition and material incentives (Z1.1), credit or scholarship incentives (Z1.2), and incentives in further education or employment (Z1.3), while the latter contains four factors, namely infrastructure construction (Z2.1), mission and curriculum (Z2.2), regulations and rules (Z2.3) and culture and atmosphere (Z2.4). The overall mean scores of the internal context scale and the external context scale were 4.29 and 4.45, respectively. Among them, Z2.1 and Z2.3 had the highest mean score of 4.49, while Z1.1 had the lowest of 4.17.

In addition, by comparing the overall mean values of attitude, behavior, and contextual factors, this study found that the mean score was in the order of X

(4.59) > Z2 (4.45) > Z1 (4.29) > Y (4.01). It shows that college students' attitude toward waste separation does not correspond to their waste separation behavior. That is to say, the waste separation behaviors of college students are not as positive as their attitude toward waste separation. In addition, relatively speaking, in the corresponding context, the performance of waste separation behaviors of college students has been greatly improved, even close to the evaluation level of attitude.

- Factors that promote and hinder waste separation. The questionnaire uses multiple choice to investigate the important factors that promote and hinder college students to participate in waste sorting. To visually display the survey results, the Pareto diagram is used here. The Pareto diagram is a graphical representation of the "80/20 principle". That is 80% of problems are caused by 20% of causes. It is necessary to find out the dominant factors and focus on them. As for promoting factors, there are four items with a cumulative sum of 70.02%, namely, B (reminding waste separation), D (setting up waste separation bins), C (implementing theme education), and A (providing courses or training), see Figure 3.8.

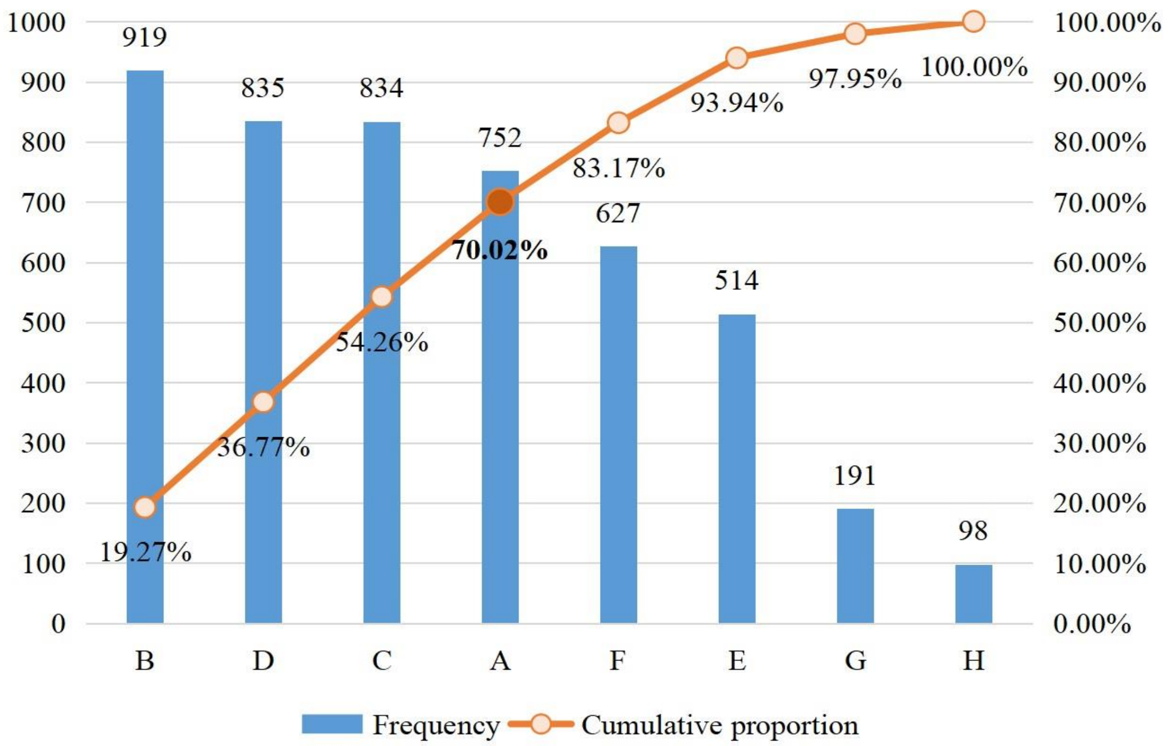

Figure 3.8 - Pareto diagram of factors that promote waste separation behaviors

Source: prepared by the author

These four items are mainly related to publicity and education and infrastructure, indicating that they are important factors to promote waste separation behaviors of college students. At the same time, the response rate and penetration rate of these four items were significantly higher. The cumulative proportion of the other four items is 29.92%, indicating that the category items are of low importance, including F (establishing incentive mechanism), E (introducing special regulations), G (taking punishment measures), and H (supervising the users). These items are mainly related to system construction and reward and punishment measures, which are relatively minor factors in promoting waste separation behaviors of college students.

Regarding impediments, there are five items with a cumulative sum of 74.47 percent, including A (knowledge deficiency), F (obsolete facility), C (taking time and energy), D (lack of incentive mechanism), and B (neglecting personal responsibility), see Figure 3.9.

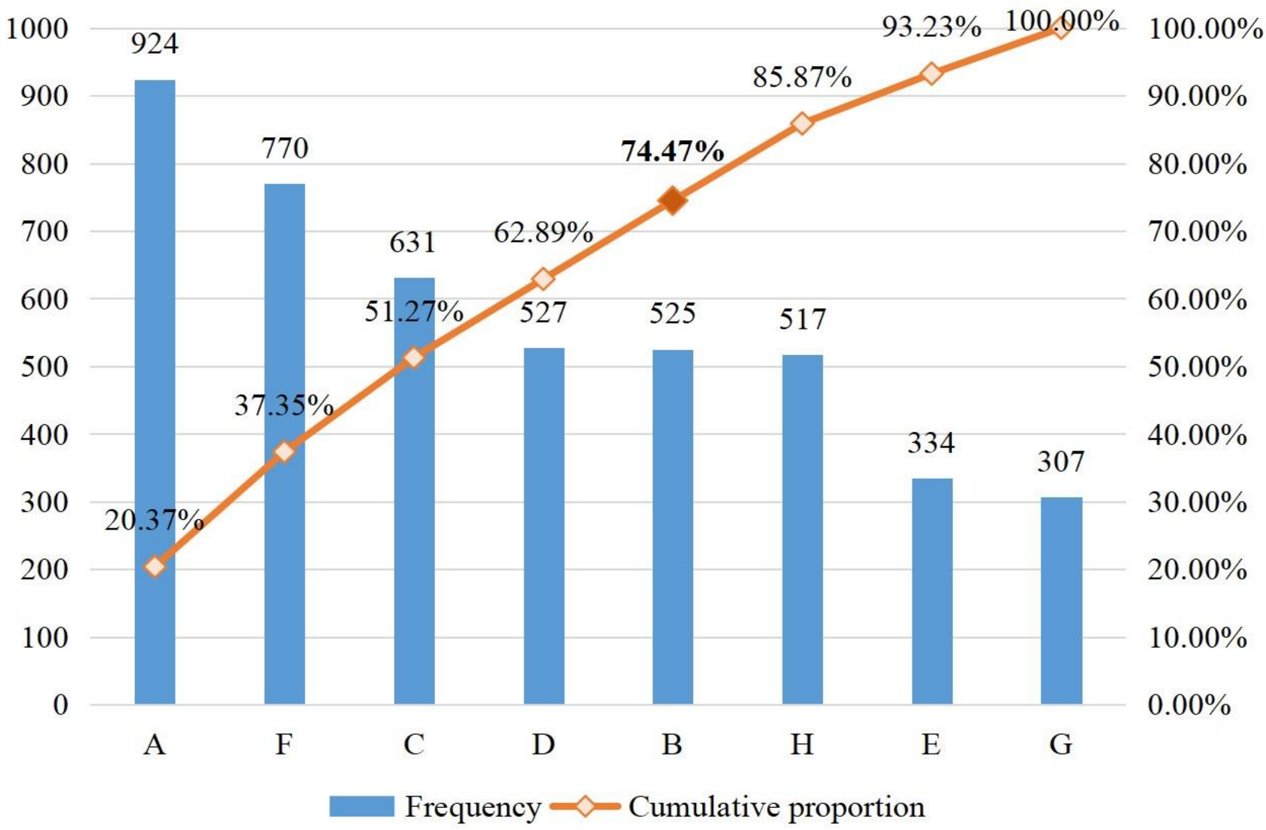

Figure 3.9 - Pareto diagram of factors that hinder waste separation behaviors

Source: prepared by the author

Comparatively speaking, the response rate and penetration rate of the first three items are significantly higher. These three items involve knowledge, infrastructure, and personal cost, so it indicates that lack of knowledge, imperfect facilities, and high personal cost are important factors hindering waste separation behaviors of college students. The remaining items are relatively minor factors hindering the waste separation behaviors of college students.

It can be concluded that the main factors hindering the waste separation behaviors of college students are the lack of relevant knowledge, imperfect campus infrastructure, and high personal investment costs. Strengthening the propaganda and education about waste separation and the construction of campus infrastructure are the main factors to promote the waste separation behavior of college students. It can be seen that the survey results about the promotion and hindrance of waste separation behaviors in universities are the same.

Inferential Analysis. Several analytical methods were used to verify the variable relationship, influence path, and regulating factors of college students' attitudes and behavior toward waste separation.

- Relationship between socio-economic characteristics and other variables. One-way ANOVA was used to study the relationship between gender and X, Y, Z1, and Z2, and it was found that respondents with different genders showed significant differences with respect to X, Z1, and Z2 ($p < 0.01$). The analysis also showed that the average value of males was significantly lower than that of females for the mentioned three variables.

Similarly, one-way ANOVA was used to study the effect of age and grade on X, Y, Z1, and Z2. The results showed that respondents of different ages show no statistical difference in terms of X, Y, Z1, and Z2 ($p > 0.05$), which indicates that respondents of different ages show consistency in all the above variables without a significant difference.

As for grades, the analysis results showed that respondents from different grades showed no significant difference in terms of X ($p > 0.05$). However, the grade of respondents showed significant differences in terms of Y, Z1, and Z2 (p <

0.01). Furthermore, based on the analysis, the mean score comparison results of the groups with significant differences in Y in terms of grade are “freshman > sophomore > junior > senior”. The comparison result of the mean score of grade groups with obvious differences in Z1 is “senior > freshman > junior > sophomore”. The comparison result of the mean score of grade groups with obvious differences in Z2 is “freshman > senior > junior > sophomore”. The research shows that waste separation behaviors tend to fade with the increase in grade. In addition, generally, the waste separation behavior of senior students is more susceptible to contextual factors. However, it should be noted that freshmen show a higher degree of activity under contextual factors; that is, freshmen show a higher willingness to waste separation under the influence of contextual factors, see Table 3.10.

Table 3.10 - ANOVA of the sample’s socioeconomic characteristics

Variable		X	Y	Z1	Z2
Gender ($\bar{x}$ ± S)	Male (n = 459)	4.53 ± 0.51	3.99 ± 0.83	4.20 ± 0.99	4.34 ± 0.77
	Female (n = 754)	4.62 ± 0.38	4.01 ± 0.74	4.35 ± 0.83	4.52 ± 0.60
	F	10.881	0.253	8.597	19.224
	p	0.001 **	0.615	0.003 **	0.000 **
Age ($\bar{x}$ ± S)	<18 (n = 39)	4.48 ± 0.49	3.99 ± 0.74	4.25 ± 0.96	4.36 ± 0.90
	18~20 (n = 801)	4.61 ± 0.44	4.05 ± 0.76	4.30 ± 0.89	4.49 ± 0.65
	21~23 (n = 365)	4.56 ± 0.43	3.92 ± 0.81	4.28 ± 0.90	4.38 ± 0.70
	≥24 (n = 8)	4.39 ± 0.55	3.81 ± 0.64	4.67 ± 0.47	4.29 ± 0.45
	F	2.075	2.398	0.524	2.472
	p	0.102	0.066	0.666	0.060
Grade ($\bar{x}$ ± S)	Freshman (n = 516)	4.62 ± 0.41	4.06 ± 0.76	4.36 ± 0.86	4.54 ± 0.61
	Sophomore (n = 316)	4.57 ± 0.48	4.05 ± 0.76	4.14 ± 0.99	4.35 ± 0.77
	Junior (n = 243)	4.54 ± 0.44	3.91 ± 0.81	4.28 ± 0.84	4.37 ± 0.68
	Senior (n = 138)	4.57 ± 0.44	3.87 ± 0.80	4.42 ± 0.83	4.47 ± 0.65
	F	2.529	3.875	4.855	6.899
	p	0.056	0.009 **	0.002 **	0.000 **

** * * $p < 0.05$ $p < 0.01$*

Source: prepared by the author

- Relationship between attitude and behavior. To understand the impact of college students' attitudes towards waste separation on their waste separation behavior, X was taken as the independent variable, while Y was taken as the dependent variable to conduct linear regression analysis. As can be seen from the following table, the model equation is:

$$Y = 0.180 + 0.834 \times X \quad (3.2)$$

As shown in Table 3.11, the R2 value of the model is 0.224, which means that X can explain 22.4% of the changes of Y. The model passed the F test (F = 349.039, p = 0.000 < 0.01), indicating that X must have an impact on Y. Finally, the analysis showed that the regression coefficient value of X is 0.834 (t = 18.683, p = 0.000 < 0.01), which means that X has a significant positive influence on Y.

Table 3.11 - Parameter estimates of linear regression analysis (n=1213)

	Unstandardized Coefficients		Standardized Coefficients	*t*	*p*	VIF	R^2	Adj *R*	*F*
	B	Std. Error	*Beta*						
Constant	0.180	0.206	--	0.874	0.382	--	0.224	0.2223	*F* (1, 1211) = 349.039, *p* = 0.000 **
X	0.834	0.045	0.473	18.683	0.000 **	1.000			

Dependent Variable: Y
D-W: 1.920
* *p<0.05* ** *p<0.01*

Source: prepared by the author

To further clarify the influence of each factor in attitude on the behaviors, X1, X2, X3, and X4 were taken as independent variables respectively, while Y was taken as dependent variables for linear regression analysis. As can be seen from the following table, the model equation is:

Y =0.294 + 0.049ЧX1 + 0.126ЧX2 + 0.385ЧX3 + 0.304ЧX4 (3.3)

The R2 value of the model is 0.349, indicating that X1, X2, X3, and X4 can explain 34.9% of the change in Y, see Table 3.12. The model passed the F test (F = 162.091, p = 0.000 < 0.01), confirming that at least one of the four elements of the X variable would have an impact on Y. In addition, the test of the model's multicollinearity showed that all VIF (Variance Inflation Factor) values in the model are less than 5, which means there is no collinearity problem. Moreover, the

D-W value is near 2, showing that the model does not have autocorrelation and there is no correlation between sample data. Therefore, the model is good. The final concrete analysis shows that the regression coefficient value of X1 is 0.049 (t = 1.485, p = 0.138 > 0.05), meaning that X1 will not have a significant impact on Y. Also, the regression coefficient of X2 is 0.126 (t = 3.197, p = 0.001 **), X3 is 0.385 (t = 19.827, p = 0.000 **), X4 is 0.304 (t = 7.444, p = 0.000 **), implying that these three factors have a significant positive influence on Y. Among them, X3 exhibited the greatest influence on the dependent variable Y..

Table 3.12 - Parameter estimates of linear regression analysis (n=1213)

	Unstandardized Coefficients		Standardized Coefficients	t	p	VIF	R^2	Adj R^2	F
	B	Std. Error	*Beta*						
Constant	0.294	0.197	--	1.495	0.135	--	0.349	0.347	F(4, 1208) = 162.091; p = 0.000 **
X1	0.049	0.033	0.041	1.485	0.138	1.386			
X2	0.126	0.039	0.093	3.197	0.001 **	1.562			
X3	0.385	0.019	0.470	19.827	0.000 **	1.044			
X4	0.304	0.041	0.199	7.444	0.000 **	1.325			

Dependent Variable: Y.

D-W: 1.889.

** p<0.05 ** p<0.01*

Source: prepared by the author

- Analysis of moderating effect. Moderating effect analysis is to study whether the influence of independent variable X on dependent variable Y will be interfered with by the moderating variable Z. In the study, the X and Z were first treated centrally, followed by hierarchical regression analysis.

In the study of the moderating effect of Z1, three models were involved in hierarchical regression analysis. Model 1 includes independent variables X. In model 2, a moderating variable Z1 was added based on Model 1, and in Model 3, an interaction term (product term of the independent variable and moderating variable) was added based on Model 2. The dependent variable of the model is Y.

The purpose of model 1 was to study the influence of the independent variable X on the dependent variable Y without considering the interference of the moderating variable Z1. As can be seen from Table 3.13, X has a significant influence on Y.

Table 3.13 - Parameter estimates of modulation analysis (*n*=1213)

	Model 1					Model 2					Model 3				
	B	S.E.	*t*	*p*	*β*	*B*	S.E.	*t*	*p*	*β*	*B*	S.E.	*t*	*p*	*β*
Constant	4.006	0.019	214.095	0.000**	-	4.006	0.019	214.166	0.000**	-	4.002	0.019	209.656	0.000**	-
X	0.921	0.041	22.334	0.000**	0.540	0.910	0.042	21.627	0.000**	0.534	0.925	0.044	20.886	0.000**	0.542
Z1						0.029	0.021	1.342	0.180	0.033	0.026	0.022	1.184	0.237	0.029
X*Z											0.050	0.047	1.062	0.288	0.027
R^2	0.292					0.293					0.293				
Adj. R^2	0.291					0.292					0.292				
F	*F* (1,1211)=498.814,*p*=0.000					*F* (2,1210)=250.473,*p*=0.000					*F* (3,1209)=167.375,*p*=0.000				
$\triangle R^2$	0.292					0.001					0.001				
$\triangle F$	*F* (1,1211)=498.814,*p*=0.000					*F* (1,1210)=1.802,*p*=0.180					*F* (1,1209)=1.128,*p*=0.288				

Dependent Variable: Y

* $p<0.05$ ** $p<0.01$

Source: prepared by the author

The moderating effect can be viewed in two ways. The first is to check the significance of the change in F value from Model 2 to Model 3. The second is to check the significance of the interaction term in Model 3. As shown in Table 3.12, the change in the R2 value is only 0.001, which is very low. Moreover, the change in the F value is not significant (p = 0.167 > 0.05). In addition, the regression coefficient B of interaction terms is 0.074, which does not show a significant value (t = 1.382, p = 0.167 > 0.05). This indicates that interaction terms are not significant, which further implies that there is no regulatory effect. In other words, when X affects Y, the moderating variable Z1 has a similar influencing range at different levels.

When studying the moderating effect of external factors on Z2, the moderating effect was similarly divided into three models, and the independent variable X was included in Model 1. In model 2, moderating variables Z2 were added based on Model 1, and in Model 3, interaction terms (product terms of independent variables and moderating variables) were added based on Model 2.

It can be seen that in model 1, X has a significant influence on Y. The ДF showed significance (F = 86.518, *p* = 0.000 **) when moving from model 2 to model 3, see Table 3.14. Moreover, the interaction term between X and Z2 exhibited that it was significant (*t* = 2.436, *p* = 0.015 < 0.05). This all implies that the magnitude of the effect of the moderating variable Z2 differs significantly at different levels when X has an effect on Y. The value of the regression coefficient of the interaction term is 0.139, which suggests that the moderating variable acts as a positive moderator of the effect of X on Y.

Table 3.14 - Parameter estimates of modulation analysis (n=1213)

	Model 1					Model 2					Model 3				
	B	S.E.	*t*	*p*	*β*	*B*	S.E.	*t*	*p*	*β*	*B*	S.E.	*t*	*p*	*β*
Constant	4.005	0.020	203.958	0.000 **	-	4.005	0.019	211.037	0.000 **	--	3.987	0.020	196.417	0.000 **	--
X	0.834	0.045	18.683	0.000 **	0.473	0.643	0.048	13.474	0.000 **	0.365	0.709	0.055	12.961	0.000 **	0.402
Z2	--	--	--	--	--	0.289	0.031	9.302	0.000 **	0.252	0.287	0.031	9.254	0.000 **	0.250
X×Z2	--	--	--	--	--	--	--	--	--	--	0.139	0.057	2.436	0.015 *	0.070
R^2	0.224					0.276					0.279				
Adj. R^2	0.223					0.274					0.277				
F	*F*(1, 1211) = 349.039, *p* = 0.000 **					*F*(2, 1210) = 230.103, *p* = 0.000 **					*F*(3, 1209) = 156.007, *p* = 0.000 **				
△R^2	0.224					0.052					0.004				
△*F*	*F*(1, 1211) = 349.039, *p* = 0.000 **					*F*(1, 1210) = 86.518, *p* = 0.000 **					*F*(1, 1209) = 5.936, *p* = 0.015 *				

Dependent Variable: Y

* *p*<0.05 ** *p*<0.01

Source: prepared by the author

The results of simple slope analysis showed that in high external contexts, high levels of college students' attitudes toward waste separation and recovery significantly predicted high levels of corresponding behaviors. Meanwhile, in the low external context, the low level of college students' attitudes also effectively predicted their low level of behaviors, see Table 3.15.

Table 3.15 - Results of the simple slope analysis

Levels of the Moderating Variables	*B*	S.E.	*t*	*p*	95% CI	
Mean value	0.709	0.055	12.961	0.000	0.602	0.816
High level (+1 SD)	0.803	0.081	9.909	0.000	0.644	0.962
Low level (−1 SD)	0.614	0.049	12.506	0.000	0.518	0.711

Source: prepared by the author

Appropriate suggestions and countermeasures. Through empirical research on data and analysis of research results, the following will discuss from the perspective of different subjects of college students, universities, and government departments, and put forward corresponding countermeasures and suggestions to promote personal green consumption habits and environmental protection living behaviors and promote the establishment of ecological civilization society.

- The level of college students. As a special group that plays an important role in leading society, it is particularly important to cultivate the awareness and behavior of waste separation among college students.

First, college students should strengthen their knowledge of waste separation. Learning waste separation knowledge is the basis and guarantee of waste separation. The study of waste sorting policies includes national laws and regulations and specific regulations formulated by local governments, which will help college students grasp current national policies and obtain the latest knowledge. University has a natural advantage compared to society, the network resources, communication between students, books, newspapers, and magazines to consult the convenience is the advantage of waste separation learning conditions, can also participate in practical activities to promote the theory knowledge learning, knowledge for waste separation learning can exert a subtle influence on improving students’ consciousness of CE.

Second, college students should go beyond the thinking of students and take the initiative to shoulder their social responsibilities as citizens. Since everyone’s production and living activities have caused the waste of resources and serious environmental problems, people should bring this sense of responsibility back to their quality, establish a sense of responsibility, and start from ourselves to reduce the human claim and damage to nature. In addition, some college students have a high awareness of environmental participation but lag in action, because they are highly dependent on the government. These college students can't aware waste separation responsibility system on their every citizen, but there is a "wait and see", "wait", and "rely on" negative psychology, then even if they think it is necessary to waste separation, there is the waste separation of subjective will, but not necessarily produce separation behavior, intention and behavior are produced by separation problems.

Moreover, college students should consciously practice a green lifestyle. The relationship between man and nature has changed from conquering nature in the past to seeking a harmonious coexistence between man and nature, which reflects the desire of all mankind to live in peace with nature. Human beings have brought harm to nature and should also assume the responsibility of protecting nature. In the past, the way of life focused on the consumption of resources, causing damage to the environment, now all countries are advocating a green lifestyle, in a simple but efficient way to protect the environment. As a concrete green way of life, waste separation is an urgent goal to be implemented. In fact, the significance of waste separation lies not only in waste separation and recovery but also in the recycling of the waste in the later stage and the advocacy of a sustainable lifestyle in the early stage. China has entered a new era. As college students in the new era, they should pay more attention to the improvement of moral quality, actively practice a green lifestyle, and improve the living environment.

- The level of university administrators. Based on the above analysis and research conclusions, the following suggestions are put forward for colleges and universities.

First, university administrators should strengthen the popularization of waste separation knowledge and cultivate students' awareness of social responsibility. Research shows that the knowledge and sense of responsibility for waste separation are the most significant factors affecting the waste separation behavior of college students. Therefore, popularizing the knowledge of waste separation and cultivating college students’ sense of social responsibility is an important measure for college students to form the behavior habit of household waste source separation. On the one hand, colleges and universities should actively carry out publicity and education in various ways to popularize waste separation knowledge, such as thematic publicity activities, general education courses, and integrating knowledge into professional education. On the other hand, should pay attention to improve the college students of national energy and environmental problems such as attention, make them understand the policies and measures of the state governance environment, such as the double goals, make them understand waste separation actions to protect the ecological environment, save energy resources in China, the importance to solve the problem of global warming, to cultivate college students’ value to waste separation behavior and sense of responsibility.

In addition, this study should pay attention to the difference in the population when conducting waste separation education for college students. In view of the low score of male college students in waste sorting attitude, attention should be paid to the performance of male college students in learning and participation in education. In addition, education may need to pay attention to the differentiation of different grades. It is necessary to pay attention to the guidance and education of senior students, and at the same time, the enthusiasm for waste separation of freshmen should be affirmed and encouraged to maintain their behavior level.

Second, university administrators should improve the construction of supporting facilities for waste separation and improve the constraints of the waste separation system. Although the country has clearly defined the classification standard of household waste and the standard identification of waste cans, many colleges and universities have not been able to improve the construction of waste separation facilities on campus simultaneously. Colleges and universities should focus on solving the defects of campus waste separation facilities' insufficiency, and unclear classification labels, reasonably purchase waste separation facilities to improve the convenience of waste delivery by college students, and make clear the labeling of campus waste separation and dumping, so as to enhance the participation of college students in front of the separated delivery.

The lack of strict school rules is one of the important reasons for the low participation of college students in waste separation. According to the research results, policy publicity is the key factor affecting the waste separation of college students. Colleges and universities should vigorously publicize and implement national and local policies on waste separation, and formulate campus rules and regulations according to local conditions. In addition to encouraging college students to actively participate in waste separation, it is also necessary to implement the responsibility assessment system to reverse and constrain illegal dumping behavior. The cultivation of personal waste separation behaviors habits not only requires encouraging college students to actively participate in practice but also requires strict accountability to regulate and strengthen their behavior. The school's system and policy measures have a strong binding force and can effectively regulate and restrain students' daily life behavior (Wei & Guo, 2020).

Third, university administrators should guide and encourage campus environmental protection activities, and actively organize and carry out waste separation practice activities. Motivation is often the source of behavioral motivation. Schools can give appropriate rewards to teachers and students for campus waste separation by formulating relevant incentive policies, which can fully reflect positive guidance. The school can arouse the interest of teachers and students and raise the level of attention by appropriately rewarding and supporting the scientific research projects, and academic and research activities conducted by teachers and students with the theme of waste separation. For the waste separation behavior design and evaluation activities of student dormitories as units, material rewards or spiritual commendations will be given to dormitories that actively participate in waste separation.

At the same time, extra-curricular practical teaching is an important link in the college education system. In addition to the daily abstract theoretical teaching, this study can carry out targeted practical activities on waste separation to realize the combination of theoretical learning and practical activities, so that students can digest and understand the connotation of theoretical knowledge in class in practical activities. The practical activities of waste separation should be indispensable content of practical education in colleges and universities. Organizing college students to visit and study waste recycling and resource recycling factories is also a good way of practical teaching, which can help college students better understand the reasons, operation process, and direction of waste separation. College students can truly feel the value of front-end waste separation, so as to consciously participate in the waste separation action.

Finally, university administrators should enrich and expand the influence range of campus publicity, and strengthen the cultural atmosphere of campus CE. The propaganda and education on waste separation should not be limited to traditional campus propaganda channels. The school should change the conventional thinking of propaganda and expand the propaganda to the modern media field and the surrounding communities of the university as an important starting point to expand the influence range of effective propaganda. For example, through modern information technology and social media platforms, such as mobile phones clients run waste sorting apps to popularize knowledge and concepts of CE. In terms of publicity objects, surrounding communities and enterprises can be considered, and CE education and waste separation behaviors guidance can be carried out for people around the campus to expand the social impact of campus publicity. Through diversification and multiple platforms, it can improve the convenience and speed of obtaining information, expand the penetration of information transmission, achieve the combination of audio-visual and more appealing, and expand the mass base of waste separation and popularize it to the whole people.

In addition, as the embodiment and externalization of school spiritual culture, campus culture is unique and independent university management guided by culture. Universities should pay more attention to creating a sustainable campus culture, cultivating students' green consumption habits and awareness of CE, and improving the atmosphere of waste reduction and sorting.

- The level of government departments. Based on the above research conclusions, the following suggestions are put forward for the separation and recovery management of Chinese urban household waste.

Firstly, the government should strengthen the construction of urban household waste separation and recovery systems. At present, most of the waste separation pilot cities have adopted various approaches to speed up the construction of waste separation infrastructure. Also, universities are simultaneously improving the campus waste separation facilities. However, the back-end classification collection, and transportation system of urban waste treatment in China is in a relatively backward state, which directly leads to the low enthusiasm of college students for front-end separation and delivery. Therefore, it is suggested that cities should further clarify the allocation of domestic waste separation and recovery facilities in construction planning, and accelerate the establishment of a complete domestic waste separation and treatment system of "separated delivery, separated collection, separated transportation, and separated disposal". At the same time, the construction of renewable resource recovery sites and the construction of standardized resource recovery systems should be accelerated to improve the convenience of recovery services.

The government should improve the construction of laws and regulations on waste separation and recycling. At present, only a few pilot cities in China have established effective laws and regulations, incentive mechanisms, and mandatory restraint policies for the management of household waste sorting and recycling. For example, Shanghai issued the Shanghai Municipal Household Waste Management Regulations in 2019. As the producers of household waste, most urban residents' participation in the separation and recovery depends on their initiative and willingness, and are not subject to laws and regulations. The government needs to strengthen the top-level design of city life waste recycling, binding and incentive policy-making of laws and regulations as soon as possible, establish management mechanisms linked to residents' vital interests, clear responsibility and obligation of residents, and form a complete set of rewards and punishment mechanism, to ensure all the residents to participate in living waste recycling, realize the effective management of urban living waste separation recycling (Meng, 2019).

3.3 Sustainable city of the future with university demonstration and contribution

Directions of Urban economic development in China. Over the past 40 years of reform and opening up, remarkable achievements have been made in China's urban development. Especially in the 21st century, the pace of urbanization has been accelerating, with tens of millions of rural people migrating to cities every year (PRC NBS, 2020), as shown in Figure 3.10.

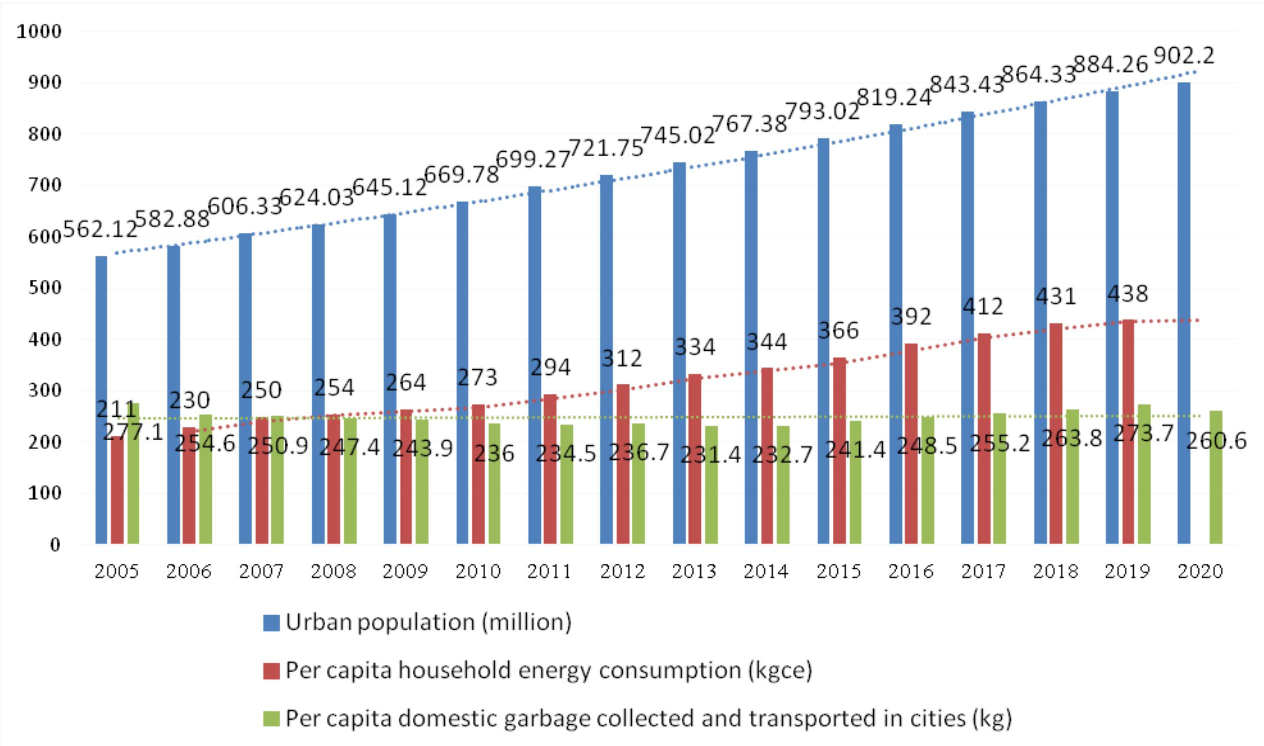

Figure 3.10 - Development of urban population and waste collection

Source: prepared by the author based on the PRC NBS (2020)

The urban population will reach 901.2 million in 2020, an increase of 17.9 million over 2019. With the continuous expansion of the urban population and the consequent transition of economic growth mode, urban development is faced with many difficulties in construction and management, such as resource shortage, environmental pollution, traffic congestion, safety hazards, and other problems becoming increasingly prominent.

The first is the problem of sustainable economic development under resource constraints. From the perspective of economics, the basic elements of economic development, such as labor force, land, resources, capital, technology, and management, are scarce resources and should be allocated to maximize returns. With the expansion of urban scale and the growth of urban population, per capita production resources or capital shortage can not grow indefinitely, so it will form the bottleneck of economic growth. Taking household energy consumption as an example, the per capita consumption level of natural gas, electricity, and other energy increased year by year. In 2020, the per capita household energy consumption reached 438kg, more than double that of 2005. Resource constraint makes the development of an urban economy must open source and reduce expenditure, that is, to economize and make intensive use of existing resources and elements, or to find new production promotion elements, new production organization forms, and new economic growth points. With the development of the knowledge economy, knowledge production and technological progress have become the endogenous driving force of economic growth, and even knowledge has replaced the labor force and capital as the only element of production (Richard, 2005). Since knowledge and technology can be created and innovated constantly, it has become the trend of urban development to relieve the resource constraints that restrict urban and economic development through scientific and technological innovation.

Secondly, economic growth brings environmental problems to urban development. According to the U-shaped curve of environmental Kuznets, with the increase of urban per capita income, urban environmental quality will experience a process of deterioration and then improvement, that is, pollution first and then treatment. Since 2005, the Chinese government has advocated the promotion of CE and taken measures to improve the environment. The per capita waste removal volume of urban residents has been decreasing year by year, reaching the lowest point in the past few years at 231.4 kg in 2013. However, with rapid urbanization, population growth, and economic development, the amount of waste collected by urban residents per capita has started to rise again. At present, the environmental problem is still an important problem troubling urban development all over the world. According to a report released by the World Bank in December 2018, the global municipal solid waste generated in 2016 was 2.01 billion tons. Global waste volume is expected to reach 2.59 billion tons in 2030 and 3.4 billion tons in 2050. Land bearing capacity will eventually reach the limit, resulting in the deterioration of urban living conditions, not suitable for living and living. Moreover, from an environmental point of view, the environmental pollution that has been caused may take a long time to repair, sometimes even irreversible. From an economic point of view, the cost of subsistence and living will increase significantly, the entire urban system will become unsustainable, and the urban economy will become uncompetitive. Therefore, the city needs to adjust the industrial structure and choose the SD path of low consumption, low emission, high benefit, and high output.

In this context, the development pattern of the city continues to evolve. In recent years, the discussion of urban development patterns are many achievements, put forward the development model in some cities, such as relying on the creative economy and new types of industrial clusters Creative City, focusing on knowledge innovation, knowledge management Innovation City and Knowledge City, emphasis on energy conservation and emissions reduction, development of low carbon industry Low-carbon City and No-waste City, Green City, Garden City, and Eco-civilized City, etc., focus on environmental protection and beautification. In recent years, with the development of a new generation of information technology represented by the Internet of Things, cloud computing, mobile Internet, and artificial intelligence, Smart City, which can enhance the development space and sustainability of cities, is considered to be the direction of urban development in the information age and the trend of civilization development. The concept of a smart city originates from the concept of smart Earth proposed by IBM in 2008. Its essence is to use modern information technology to promote the interconnection, efficiency, and intelligence of urban operation systems, which can make urban resources more easily to be fully integrated. In other words, based on the fine and intelligent management of the city, reduce resource consumption and reduce environmental pollution, so as to realize the SD of the city. China has been building smart cities since 2012, approving 90 national smart city trials for the first time. By the end of 2017, more than 500 cities in China have proposed or are building smart cities. In short, from the general trend and practice of modern city development, the future urban development should be an SD road driven by knowledge and science, and technology, that is, knowledge innovation and SD are the main driving forces of the future modern city development. This means that universities with rich educational and research assets are increasingly connected to the cities of the future.

Driving effect of universities on urban CE implementation. The development of universities can guide and drive the economic and social development of cities. CE-related university assets and urban CE development have different levels and content of the relationship. In this relationship, CE-related university assets can be an important driving force of urban economic and social development, as well as a symbol of urban CE. When a city develops to a new stage, it mainly depends on high-quality innovative talents and other external environments. Therefore, compared with the competitiveness of other regions, the existence of research-oriented universities in the region will give the region more comparative advantages (Audretsch et al., 2012). The universities in the region can exert an important influence on the development of the region in CE personnel training, scientific and technological innovation, and social services.

- **Direct knowledge production and knowledge spillover.** Derek, a famous American educational thinker and former president of Harvard University, believes that universities are designed to fulfill the special mission of discovering and transmitting knowledge (Bok, 1990). The university will become the knowledge center of the learning society and the axis organization of modern society. The industry in the new century will increasingly rely on the production of knowledge. With its advantages, universities can provide new knowledge and disseminate new technologies (Brostrm, 2010). In terms of learning and updating knowledge, and in terms of cultivating innovative talents (Acosta et al., 2009), they are all in a central position, playing the role of core leaders to promote the development of social economy and culture.

- **Direct and indirect innovation influence.** It directly produces technological innovation, knowledge innovation, product innovation, and management innovation, and indirectly produces business model innovation and social and economic management innovation. In fact, creativity, as an economic form, has risen to the level of national policy (Hesmondhalgh, 2007). Universities have their unique advantages in innovation. The implementation of green universities on green scientific research, green projects, and green products is reflected in the improvement of innovation efficiency and quality. While changing people’s original concepts, consumption patterns, and lifestyles, it will also generate new business models and new management patterns, thus forming new models and directions for urban development.

- **Advantages in analyzing and disseminating culture.** Universities are always based on national culture, facing the world and the future. Each university has its own unique regional culture, disciplinary characteristic culture, and historical accumulation. The interpretation of the scientific spirit and cultural tradition can radiate and influence students, teachers, and other social strata. The combination of green culture and university culture can make better use of the situation, carry forward its advantages, and focus on spreading the concept of SD in a certain area or region, which will fundamentally have a huge ideological impact on the SD of the society.

- The role of the creative economy and urban networking. The external conditions of the creative economy are mainly the proximity to comprehensive universities and the cosmopolitan city. In the development of modern industry, universities are increasingly important for the creative economy of cities or regions. Harvard University established the Harvard Council on the Environment in 1991 to encourage and coordinate university-wide activities and academic research related to the environment. As a world-renowned university in science and technology, Massachusetts has made outstanding achievements in green technology, such as green building, green supply chains, and green energy-saving technology. The two universities have had a significant impact on the formation of their region, the route 128 area, and the emerging biotechnology cluster. In China, Beijing and Shanghai also show similar characteristics. For example, there are many famous universities led by Peking University and Tsinghua University around Beijing Zhongguancun Science Park, forming knowledge spillover and industrial cluster effect. With the core concept of "integration and joint development of the three districts", Tongji University and the city where it is located jointly build a knowledge economy circle around the Siping Road campus. The creative economy is often a green economy, and the construction of green universities reinforces this characteristic, making innovation and development more competitive.

- As a demonstration community in a sustainable city. One development trend of campus is a university city, such as Oxford and Cambridge university city in Britain, while Chongqing University City in China is a big city integrating science and technology, education, culture, and ecological niche with a total population of 1 million. In fact, the university town has become a characteristic community of the city where it is located, radiating to its surrounding areas in terms of knowledge, culture, technology, environment, and lifestyle. The construction of green campuses will become a typical demonstration area of green environmental protection, green management, and green economy in the whole society with the wide use of green building technology and the new generation of energy-saving technology. Reference cases are provided for unhealthy urban and regional development problems caused by a lack of corresponding capacity to carry out changes and adapt to changes in resources, environment, economic foundation, and social conditions (Disterheft et al., 2012).

Specifically, colleges and universities can provide the continuous impetus for the development of urban CE through rich CE-related assets. On the one hand, CE-related education activities will reshape knowledge and talent, which will fundamentally change the development concept and behavior culture. The influence mechanism of education is diffuse. It exerts influence through the flow of people and knowledge, and gradually forms CE consciousness and values that are generally accepted on campus and even the whole society after long-term dissemination and precipitation. On the other hand, CE-related scientific research activities can realize the outward diffusion of knowledge and technology, transform it into productivity, and promote the transition of development mode. The application of CE science and technology will affect the change of enterprises' technological innovation concept, operation and management model, and social business mode, and then affect the development of CE in cities and regions. In addition, CE campus practice can not only give full play to the CE potential contained in the university campus itself, but also provide experience and solutions for social CE planning and practice as a large community with urban functions, and conduct significant policy effect simulation for social managers.

Design of waste separation management system based on AI technology. To explore the practical significance of CE-related university assets in urban development, this study still takes waste management projects as an example to prove. The Chinese government attaches great importance to the construction of urban waste sorting and recycling system and has carried out the pilot construction of waste sorting and recycling in many cities. Since 2019, China has entered a new stage of institutionalization of waste separation, which is reflected in the fact that many cities have started to comprehensively implement mandatory waste separation. However, there are still many problems in the separation and treatment of municipal solid waste, such as incomplete community separation facilities, insufficient separation consciousness of residents, inaccurate separation, and repeated separation caused by mixed transportation. The development and application of artificial intelligence technology in smart city systems provide a more effective alternative to solve these problems.

Based on thinking learning and construction, AI could improve the efficiency of waste separation recycling and reduce the amount of solid waste entering landfills and incineration power plants through intelligent identification, collection, and sorting of waste. Moreover, the AI waste separation recycling device could make use of Big Data, the Internet of Things, and other technologies to realize intelligent waste separation management with the combination of supervision functions (Nowakowski et al., 2020). It can be predicted that the application of AI technology in waste separation management is a development direction in the future, which will change the traditional crowd management tactics. At present, companies committed to AI technology development have launched several AI-based waste collection and sorting products and applied them in some areas. However, most business users and the community have been deterred by the high price tag in promoting them to a wider audience. Universities are also crucial subjects of AI technology research and development other than specialized technology companies. To date, there have already been 35 universities in China that set up AI faculty dedicated to AI education promotion and technology research (Fu et al., 2021), which provides convenient conditions for the implementation of AI waste separation management programs on campus. A new low-cost AI waste separation system developed at Liverpool Hope University has confirmed the advantages of universities in applying AI technology to waste separation recycling management (Myers & Secco, 2021).

AI technology has been utilized to improve existing solid waste management schemes throughout the different stages, from collection to final disposal (Kolekar et al., 2016; Vitorino et al., 2017). In the context of mandatory promotion of waste separation, researchers began to focus on the application of AI technology in waste separation recycling, which is a crucial approach to solving the problem of surging waste generation and low efficiency of manual separation. The literature review conducted by Abdallah et al. (2020) indicated that the frequently used AI models in waste separation included Artificial Neural Networks, Support Vector Machines, Linear Regression, Decision Trees, and Genetic Algorithms. As for the launched AI products in the field of waste separation recycling, it is mainly divided into three categories, namely, waste separation software based on AI technology, AI waste separation container, and AI waste sorting facility. These three types of products are respectively applied in the process of waste dumping, separated collection, and sorting treatment.

The identification and guidance AI software applied in the process of waste dumping is mainly based on machine vision technology and big data technology to assist users to identify waste and confirm the correct category (Zeng et al., 2021; Yu & Jing, 2020). For example, smart waste separation small program of mobile social media APP, Oscar smart waste separation system designed by Intuitive AI, and Vivo AI assistant in China. AI recognition terminals applied in waste separation and collection are mainly used to automatically classify and collect waste based on different AI models (Kang et al., 2020; Vrancken et al., 2019; Nañez-Alonso et al., 2021; Adedeji & Wang, 2019), such as Bin-E of Poland and Smart trash Bin "Rui Bucket" launched by Alfeisi of China. Intelligent sorting facilities applied in waste sorting and processing mainly uses artificial intelligence technology to correctly sort waste collected according to categories (Tehrani & Karbasi, 2017; Chidepatil et al., 2020; Wilts et al., 2021), such as FANUC, MIT, and Alphabet The company, Finland Zeen Robot company set up the waste sorting robot project, China’s Zhongcheng Green Construction and Anqi Intelligent Technology and other enterprises launched the waste sorting robot products.

Overall, the research on AI applications in the field of waste separation management covers the three important processes of waste separation recycling, namely, dumping, collection, and sorting. According to the findings of scholars and technology companies, the AI software for classification education and guidance applied in the dumping process has been relatively mature, and the results in the collection process are the most abundant. Also, the relevant research and products in the AI sorting process are still in their infancy due to the limitations of technology and capital investment. Anyway, the previous research provides an important basis for the construction of an AI-based waste separation recycling system at universities, which has tremendous potential for promoting waste separation into the orbit of CE (Shevchenko et al., 2021).

Based on the waste separation situation at H university, integrating AI into the waste separation management process seems to be the best alternative solution to resolve the mess before the urban waste separation system gets upgraded. Implementing waste separation recycling requires abundant human resources to guide and supervise, and numerous labor efforts in the waste collection and sorting process. AI technology could not only replace part of the labor force in waste separation but also improve the performance of waste separation on campus. This study proposes a framework of waste separation management based on AI technology, which mainly involves the main processes including dumping, collection, and sorting. Specifically, the AI software could be applied in the user's waste dumping process to reduce the amount of guidance and supervision personnel that are invested in the publicity and education of waste separation knowledge. The application of an AI separation terminal in the waste collection process can realize secondary separation based on manual separation to maximize recycling and minimize landfill or incineration. AI sorting facilities could be used in the waste sorting process to reduce the labor cost caused by inefficient manual sorting and save the value of all kinds of recyclable materials.

The main processes of waste separation on campus require AI participation to ensure the action effects. In the four categories of waste, Food Waste and Hazardous Waste are difficult to be classified by AI due to their characteristics of pollution, so it is of great importance to guide and supervise users to correctly classify them through AI technology in the dumping process. Residual Waste is complex and eventually flows to waste incineration power plants or landfills, so AI separation facilities should be applied to re-classify them to increase recycling and reduce incineration and landfills. All recyclable waste should be finely sorted by an AI sorting facility and then exported to make recycled products for consumers. Finally, all waste streams are directed to corresponding docking institutions, including renewable resource plants, food waste recycling plants, hazardous waste treatment plants, and municipal sanitation systems, see Figure 3.11. In this framework, this study removed the role of junkmen because their work is replaced by an AI sorting facility. Also, it would reduce the potential health risks posed by direct exposure to waste, especially at the critical time of the global COVID-19 pandemic.

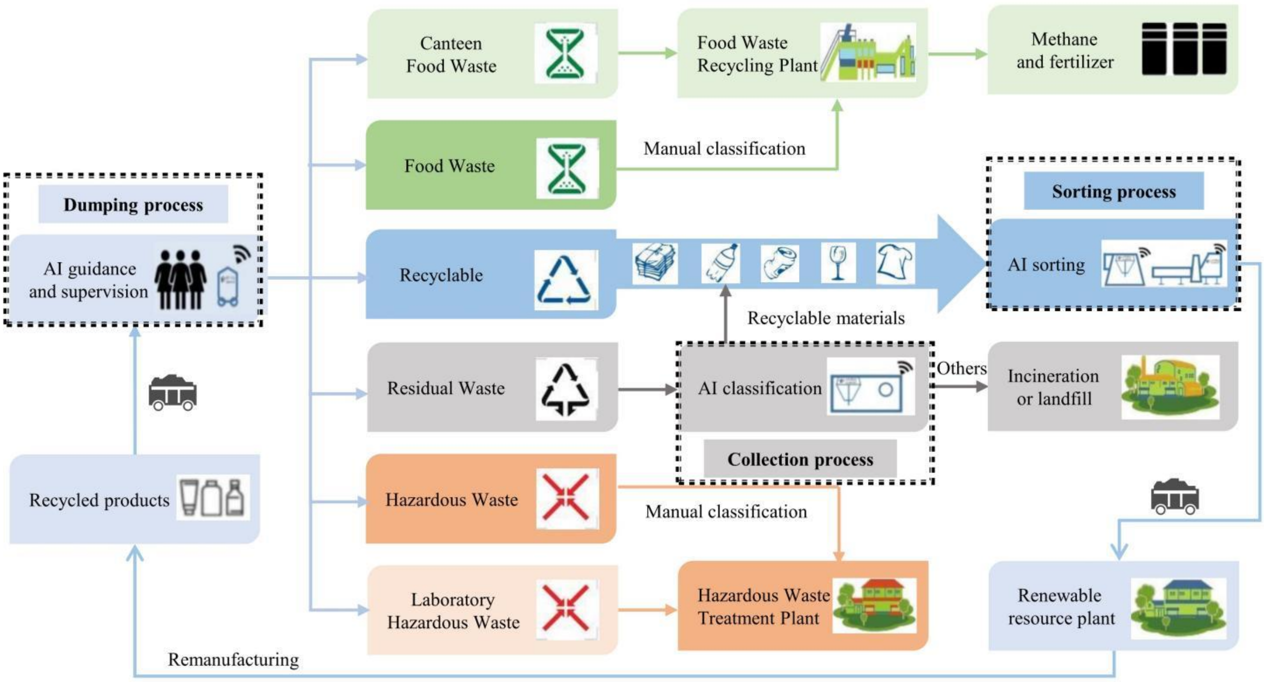

Figure 3.11 - A framework of AI-based waste separation management on campus

Source: prepared by the author

From the briefcase description above, it can be seen that the construction of intelligent waste management systems in universities mainly focuses on AI guidance and supervision in the waste dumping process, and there are still few practices in mixed waste separation and fine sorting of recyclable waste by using AI technology. It is acknowledged that the framework of AI-based waste separation management at H university proposed in this study is only in the stage of theoretical exploration and needs the support of subsequent empirical studies. On the upside, the flourishing AI faculty established in colleges and universities could carry out empirical research on AI waste separation management programs on campus, which could bridge the gap between theory and reality.

Conclusions to section 3

In section 3 “Case study of waste management program in Chinese university”, the construction of campus waste separation and recovery management system was selected as a representative of the university CE-related asset management system for a case study. This study analyzed the experience of Leiden University in waste management and the current situation of H University’s waste management program in China. Meanwhile, this study conducted an investigation on the waste separation attitude of H university students based on cognitive behavior theory. To realize the university's demonstration and contribution to the future sustainable city, this study explored the design of a waste management system based on AI technology. This study draws the main conclusions as follows.

1. From the perspective of management functions, this study analyzed the experience of Leiden University in waste management. Leiden university’s waste management plan and goals are set out in its environmental policy plan, which elaborates on how it intends to operate to meet its responsibilities in the area of environment and sustainability. This study listed the specific goals, responsible departments, and implementation status of the accountabilities in the fields of education and research, and waste. It is found that Leiden University has adopted a three-pronged approach to reduce waste for achieving the waste management goals, including preventing waste, separating waste, and recycling. The annual sustainability report is an effective way to demonstrate the effectiveness of waste management and the university’s continuous commitment to sustainable development.

2. A survey on the current situation of waste management at H University in

China is conducted to clarify the problems in process of waste management, such as lack of plans and related organizations, lagging waste classification standards and equipment, low degree of waste separation and recovery, insufficient waste classification education and publicity, and lack of control and supervision measures. Based on the enlightenment from Leiden University, the appropriate countermeasures and suggestions are put forward for H university. Furthermore, this study attempts to propose a specific waste management program for H University, which could help H University to implement waste management into practice in the top to bottom approach.

3. The questionnaire on waste management status at H University is compiled based on the cognitive behavior theory and previous research scales. A questionnaire survey was conducted at H university with 1300 respondents, among which 1213 questionnaires were valid (with an effective rate of 93.3%). The results of statistical analysis show that the attitude of respondents towards waste separation is relatively positive. Specifically, college students are generally aware of the importance of waste separation and their responsibility in realizing waste separation and recovery, but lack knowledge about waste separation. Regarding waste separation behaviors (Y), college students are generally able to participate in the propaganda and promotion activities of waste separation, but their waste separation behaviors are relatively inadequate in practice. Context factors can positively influence waste separation behaviors to vary degrees, among which the infrastructure construction (Z2.1) and the regulations and rules (Z2.3) have the most significant impact (mean value=4.49).

4. According to the Pareto principle (80/20 principle), four dominant promoting factors mainly affect waste separation behaviors of college students, including reminding waste separation, setting up waste separation bins, implementing theme education, and providing courses or training. Meanwhile, the five hindering factors are knowledge deficiency, obsolete facility, taking time and energy, lack of incentive mechanism, and neglecting personal responsibility. The results of the further analysis show that different gender respondents are significant

differences in respect of attitudes (X), internal situation factors (Z1), and external situation factors (Z2) ($p < 0.05$). Specific analysis showed that the average value of males was significantly lower than that of females for the above variables. The respondents of different ages showed consistency in all the variables without a difference. The respondents of different grades show significant differences in Y, Z1, and Z2 ($p < 0.05$). Generally, freshmen show the highest degree of waste separation behaviors. Waste separation behaviors of senior students and freshmen are more susceptible to situation factors.

5. The results of linear regression analysis show that X has a significant positive influence on Y, especially the awareness (X2, t=3.197, p =0.001**), knowledge (X3, t=19.827, p =0.000**), and responsibility (X4, t=7.444, p =0.000**). Through the hierarchical regression analysis, it is found that the moderating variable Z1 has a similar influence range at different levels when X affects Y. On the contrary, the moderating variable Z2 has a significant difference in the impact amplitude at different levels when X affects Y. Based on the above analysis, appropriate suggestions and countermeasures are proposed for college students, university administrators, and the government departments respectively.

6. This study argues that it is of practical significance to apply AI technology in waste management at H University to improve the performance of waste separation and recovery. A framework of AI-based waste separation management on campus is proposed, which mainly covers the application of AI technology in the main process of waste separation and recovery, including waste dumping, separated collection, and sorting. With the assistance of AI technology, correct dumping and accurate collection and sorting of all kinds of waste could be realized. This AI-based waste separation management system could provide references for the promotion of the municipal intelligent waste management system in future sustainable cities.

CONCLUSIONS

This study systematically reviewed the relevant literature and summarized the theories on the scientific issue of universities' potential in promoting the CE transition and putting forward new alternatives for decision-makers. The theoretical framework of the CE-related university assets management system based on full consideration of CE-related university assets and CE-related activities was proposed to expand the university's influence in CE implementation. To facilitate this theoretical system from theory to reality, a case study of a waste management program on campus was conducted to explore its practical value.

In the course of the research, the following conclusions were obtained.

1. Through the systematic review of the relevant literature, it is clarified that the institutional design, technological progress, and pilot experience dissemination are the significant dependence for China to realize CE transition. The university assets, including scientific research assets, educational assets, and campus operation assets, are closely related to these dependency factors. Further analysis reveals that the main drivers of CE in China are government policy support, public participation, economic benefits, CE awareness and knowledge, and CE technological support, and the main barriers to CE are cultural barriers, market barriers, regulatory barriers, and technological barriers. The results suggest that universities could exert an enormous influence on strengthening the drivers and eliminating barriers to CE through educational and scientific research activities, which implies that universities have bright prospects in speeding up the CE transition.

2. This study highlights that it is a realistic need and inevitable choice for universities to participate in the CE transition. However, the previous research on university CE activities is fragmented and disconnected from each other, which mainly focuses on the construction and talent training model of CE-related majors, explicit and implicit curriculum design, instruction approaches and tools, and CE practice on campus. The lack of a comprehensive management system that can

integrate these various isolated activities for an augmented effect has led to the emergence of this study.

3. The management practice of sustainable universities has experienced continuous progress and development from built environment certification to EMS and then to SMS. It’s essential to establish a more practical and down-to-earth CE management system in universities compared to SMS. The management system of CE-related university assets must be a two-way hybrid management model like sustainable universities, that is, a mixed management model of a top-down approach and participatory approach to guarantee the realization of SDGs. This raises the need for a clear implementable CE framework for universities, as well as active teachers and students with CE concepts and values.

4. It was highlighted that university educational assets possess potential in promoting CE implementation, which is mainly reflected in the aspects that include promotion of specialty development and talent cultivation, improvement of the curriculum setting, enhancement of education function of the hidden curriculum, enrichment of general education of CE, construction of teacher team of CE related majors, and the extension of the influence and scope of education radiation. Moreover, the results of empirical analysis of the spillover effect of university knowledge space show that university knowledge innovation has a considerable impact on the innovation activities of enterprises in the neighboring region. That is, the university's scientific research assets could promote the technological innovation activities of enterprises in adjacent areas, which are the critical links required for CE implementation.

5. This study introduced into scientific use the term CE-related university assets and provided classifications of these CE-related assets, as well as the attributes of CE-related university assets, such as non-profit status, technology innovation, education, propagation, and efficient use of resources. Based on the connotation and extension of the new terms, this study developed a systematic theoretical framework for CE-related university activities, which integrates various CE activities in a unified management system rather than simply patching them

together in expanding the university influence in the CE transition.

6. By analyzing the evaluation methods of sustainable universities, this study created the evaluation method and implementation standards of CE-related university assets management performance based on full participation theory. In this evaluation index system, all faculty and staff should participate in the content and process monitoring as evaluation subjects to ensure the effectiveness of the evaluation index system, which is more reliable than the traditional method of subjective self-evaluation. The basic contents of this evaluation index system include the target layer, the criterion layer, the domain layer, and the index layer, and each indicator is assigned its weight. The circularity degree is divided into five levels based on the final score calculated by the specified formula, including no circularity, low circularity, moderate circularity, high circularity, and deep circularity.

7. This study analyzed the experience of Leiden University in waste management from the perspective of management functions, such as planning, organizing, leading, and controlling. Through the analysis of the current situation of waste management at H University in China, it is found that there are some problems in process of waste management, such as a lack of plans and related organizations, lagging waste classification standards and equipment, low degree of waste separation and recovery, insufficient waste classification education and publicity, and lack of control and supervision measures. The experience of Leiden University can provide a lot of enlightenment for H University. Therefore, this study proposed a specific waste management program for H University, which could help H University to implement waste management into practice in the top to bottom approach.

8. A questionnaire survey was conducted with 1213 valid respondents at H university based on the self-designed questionnaire. The results of statistical analysis show that the respondents' attitudes (X, mean value=4.59) and behaviors (Y, mean value=4.01) regarding waste separation are relatively positive. The internal situation factors (Z1, mean value=4.29) and external situation factors (Z2,

mean value=4.45) can positively influence waste separation behaviors to vary degrees. The results of linear regression analysis show that X has a significant positive influence on Y, especially awareness (X2), knowledge (X3), and responsibility (X4). Through the hierarchical regression analysis, it is found that the moderating variable Z1 has a similar influence range at different levels when X affects Y. On the contrary, the moderating variable Z2 has a significant difference in the impact amplitude at different levels when X affects Y.

9. In the process of smart city construction, it is of practical significance to apply AI technology in waste management at H University to form demonstration communities. This study proposes a framework for AI-based waste separation management on campus, which mainly covers the application of AI technology in the main process of waste separation and recovery, including waste dumping, separated collection, and sorting. With the assistance of AI technology, correct dumping and accurate collection and sorting of all kinds of waste could be realized. This AI-based waste separation management system could provide references for the promotion of the municipal intelligent waste management system in future sustainable cities.

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APPENDIX A

Questionnaire of Waste Separation and Recovery Status at H University

It would be our great pleasure if you join this scientific survey!

The purpose of our study is to identify the primary elements affecting the achievement of waste management at H university.

We would like to emphasize that the survey is anonymous, all data received is strictly confidential and your answers will not be passed on to third parties.

The survey is conducted online and will take approximately 5 minutes. There are no right or wrong answers, it is just your vision. Your opinion is important to us!

Many thanks for your time and interest!

Part 1. Please choose the most appropriate option depending on your situation.

1. Your gender: A. Male B. Female
2. Your age: A. < 18 years old B. 18–20 years old C. 21–23 years old D. ≥ 24 years old
3. Your grade: A. Freshman B. Sophomore C. Junior D. Senior

Part 2. Please choose the most appropriate option according to your practical actions and thoughts in your daily life.

1. Do you agree that the mass generation and unreasonable disposal of waste will have a negative impact on your life and health?

A. Totally agree

B. Generally agree

C. Neutral

D. Generally disagree

E. Totally disagree

2. Do you agree that waste separation and recovery at universities is significantly meaningful for solving resource scarcity and environmental problems?

A. Totally agree

B. Generally agree

C. Neutral

D. Generally disagree

E. Totally disagree

3. Do you know the national standards for domestic waste classification (four major categories, including Recyclable Waste, Hazardous Waste, Food Waste, and Residual Waste, and 11 sub-categories)?

A. Very clear

B. Generally clear

C. Half-and-half

D. Not very clear

E. Totally have no idea

4. Do you agree that it is the responsibility of every citizen to separate waste?

A. Totally agree

B. Generally agree

C. Neutral

D. Generally disagree

E. Totally disagree

5. You always participate in the publicity and education activities on waste separation organized by the university.

A.Totally consistent

B.Generally consistent

C.Half-and-half

D.Generally inconsistent

E.Totally inconsistent

6. You always take the initiative to separate the generated waste in your daily life.

A.Totally consistent

B.Generally consistent

C.Half-and-half

D.Generally inconsistent

E.Totally inconsistent

7. You always drop off your old and unwanted clothes at the special textile recycling bins on campus.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

8. You always return the carton/box to the courier for recycling when you receive the parcel.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

9. Do you agree that waste separation is mainly the responsibility of the government and has little to do with individuals?

A. Totally agree

B. Generally agree

C. Neutral

D. Generally disagree

E. Totally disagree

10. If there is a recognition or material reward mechanism at your university, you will separate the waste.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

11. If you can get extra points in the evaluation of merit and scholarship, you will separate the waste.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

12. If you can have priority in the entrance examination and job application, you will actively participate in waste separation and the relevant practical activities.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

13. If there are standard waste classification bins and special waste collection points on campus, you will separate the waste.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

14. If your university has mandatory rules and requirements on waste separation, you will comply with the rules.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

15. If all your acquaintances around you carry out waste separation and recovery, you will separate the waste, too.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

16. The publicity campaign and courses on waste separation will make you more enthusiastic about involving in waste separation activities.

A. Totally consistent

B. Generally consistent

C. Half-and-half

D. Generally inconsistent

E. Totally inconsistent

17. Please rank the importance of the following barriers to college students' waste separation and recovery from the highest to the lowest.

A. Insufficient knowledge of waste separation and recovery

B. Lack of CE awareness and values

C. Lack of personal social responsibility

D. Waste separation takes up lots of personal time and energy

E. There is no incentives or penalties for waste separation and recovery at university

F. Campus waste separation and recovery facilities are not in line with national standards

G. The university has not issued relevant rules and regulations

H. Lack of overall atmosphere for waste separation and recovery on campus

I. Lack of publicity and education on waste separation and recovery at university

J. Others (please specify)

18. Please rank the importance of the following dynamic factors that could motivate waste separation and recoveries on campus from the highest to the lowest.

A. Providing waste separation and recovery-related courses or training

B. Setting up waste separation and recovery banners on campus

C. Adding volunteers to remind waste separation at the waste drop-off point

D. Implementing publicity and education activities on the theme of waste separation and recovery

E. Adding national standard waste separation and recovery facility

F. Introducing a clear waste separation and recovery system

G. Setting clear incentives and penalties on waste separation and recovery

H. Initiating a cultural atmosphere of waste separation and recovery on campus

I. Adding special personnel to supervise waste separation and recovery

J. Others (please specify)

APPENDIX B

Application Certification

On the implementation of the results of scientific work on the topic "Formation of management system of university's educational and scientific assets in the context of transition to the model of circular economy in China" by Candidate of Management, Ph.D. Student of the Faculty of Economics and Management of Sumy National Agrarian University Qu Dongxu in the work of the School of Education Science of Henan Institute of Science and Technology

The results of the scientific work "Formation of management system of university's educational and scientific assets in the context of transition to the model of circular economy in China", performed by Qu Dongxu, Ph.D. Student of the Faculty of Economics and Management of Sumy National Agrarian University, were used in the work of the School of Education Science of Henan Institute of Science and Technology in the development of the "Fixed assets management plan".

School of Education Science
of Henan Institute of Science and Technology
教育科学学院
February 09, 2023

APPENDIX C

Application Certification

On the use in the educational process of the results of the research "Formation of management system of university's educational and scientific assets in the context of transition to the model of circular economy in China" by the Ph.D. student of the Faculty of Economics and Management of Sumy National Agrarian University Qu Dongxu

The results of scientific research within the framework of the work "Formation of management system of university's educational and scientific assets in the context of transition to the model of circular economy in China" prepared by Qu Dongxu, Ph.D. Student of the Faculty of Economics and Management of Sumy National Agrarian University, are used in the educational process of Henan Institute of Science and Technology. In particular, the research materials are used in teaching the disciplines "Educational Dissemination" and "Pedagogy" for undergraduate students majoring in 040104 Educational Technology.

School of Information and Engineering
of Henan Institute of Science and Technology
February 09, 2023