A Study on the Carbon Footprint of Reader Behavior in the Process of Library Services——A Case Study of Jinan University Library

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Abstract. Library services are reflected through reader behavior, and the intentions behind these behaviors provide a basis for improving library services. Therefore, studying the carbon footprint of reader behavior in the process of library services is of great practical significance for enhancing the quality of library services and maximally meeting readers' information needs. Currently, the application levels of carbon footprint can be divided into four categories: individual carbon footprint, product carbon footprint, enterprise carbon footprint, and national/city carbon footprint. Individual carbon footprint refers to the process of estimating the carbon emissions caused by daily activities such as eating, clothing, housing, and transportation.

Keywords: reader behavior; carbon footprint; low-carbon services; library

1. The Role of Library Services in Low-Carbon Society

With societal development and the continuous expansion of industrial scale, global climate warming is becoming a significant issue. Many countries have realized the importance of environmental protection, and China has proposed the concept of "lucid waters and lush mountains are invaluable assets." Besides protecting the environment through laws and regulations, there is also a need to guide people in establishing a low-carbon cultural mindset, fostering environmental awareness in all aspects of work and life. Libraries, as cultural and knowledge centers in universities, play a crucial role in promoting this mindset. The carbon footprint generated during library services is vital in a low-carbon society. [1]

To manage libraries effectively in a low-carbon manner, it is necessary to establish a scientific system and evaluation standards based on practical experience. Using data to support management, improving service models, maximizing resource savings, reducing energy consumption in work and study, lowering various waste emissions, cutting management costs, enhancing management efficiency, and creating a conservation-oriented, efficient, green, and healthy reading environment and work atmosphere are all critical. Libraries can achieve this by constructing green, eco-friendly low-carbon buildings, establishing a "low-carbon awareness," and managing libraries with low-carbon principles, ensuring that every reader's behavior adheres to low-carbon and environmental protection concepts, instilling the idea of environmental protection starting with oneself. [2]

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2. Analysis of Reader Behavior's Carbon Footprint

A. Understanding Reader Behavior

Human behavior is a very complex issue. All actions in daily life can be considered behaviors. Psychologists believe behavior results from the interaction between individuals and the environment. Library reader behavior mainly refers to the reading behavior of library users. While each reader's purpose for visiting the library may vary, their behaviors share the following common points:

- Spontaneity. Visiting the library is a spontaneous act of learning, not a passive one. External forces may influence but cannot initiate the behavior; external power or commands are unlikely to cause genuine loyalty behavior.
- Purposefulness. Every reader comes to the library with a specific cause and goal, even if some behaviors seem illogical; they align with personal goals.
- Persistence. Each behavior aims for an ultimate goal; the approach may change during implementation, but the behavior will not cease until the goal is achieved, possibly shifting from explicit to implicit behavior.
- Modifiability. Readers, as the main activity body in libraries, enter the library with goals and frequently change behavior methods to achieve these goals, often through learning and training, reflecting the plasticity and referentiality of higher animal behavior.

Understanding these common characteristics of reader behavior helps explore management rules and improve service levels. The basic unit elements of reader behavior are needs, with all behaviors comprising a series of needs. A critical task of management work is to understand, predict, and control what needs readers might have and what motivations or environments may trigger their behavior needs at specific times. [3]

B. Decomposition and Calculation of Reader Carbon Footprint

1) Constructing a carbon footprint model for library services based on LCA

Based on the theory of life cycle assessment and the industrial characteristics of library services, the study investigates the carbon footprint of reader behavior during library services. Combining the analysis of reader carbon footprints in Jinan University Library and adhering to six principles—consumption traceability, service identification, regional sharing, boundary determination, industrial specificity, and operability—a carbon footprint model for reader behavior during library services is established. [4]

2) Basic situation of reader survey in Jinan University Library

a) Survey methods

This survey employed a stratified sampling method to sample faculty and students. All students of Jinan University served as the student sampling population, with over 500 students sampled, distributed across various departments and grades. For faculty, over 100 individuals were sampled, distributed across different teaching departments. Faculty and student surveys used a unified questionnaire covering aspects such as library visit frequency, average stay duration, and main purposes for visiting the library. The questionnaire primarily used multiple-choice questions to save respondents' time, with an open-answer section for additional comments and explanations.

b) Distribution and collection of questionnaires

The questionnaires were distributed in various ways. Some student questionnaires were distributed by class, while others were handed out randomly in library reading

rooms and circulation points. Faculty questionnaires were mainly distributed and collected through teaching secretaries in each college, with fewer distributed to functional departments and other teaching units. A total of 650 questionnaires were distributed, and 641 were recovered, including 538 student questionnaires and 103 faculty questionnaires.

c) Survey results and analysis

Regarding the usage of the library by readers, the survey covered three aspects: frequency of library visits, average stay duration, and main purposes for visiting the library.

• Frequency of library visits

Among the 641 respondents, student readers significantly outnumbered faculty readers. Notably, 20% of readers visited the library less than once a month (2% never visited, 4% visited once a semester, and 14% visited once a month, totaling 20%). This was particularly prominent among faculty readers, with 55% visiting the library less than once a month (6% never visited, 18% visited once a semester, and 31% visited once a month, totaling 55%). See Table I for details.

TABLE I. FREQUENCY OF LIBRARY VISITS

Frequency of Library Visits	**Students**		**Faculty**		**Total Proportion**
	Number	***Percentage***	***Number***	***Percentage***	
3 times or more per week	131	24	4	4	21
1-2 times per week	210	39	17	17	36
Once every 2-3 weeks	122	23	23	23	23
Once a month	61	11	31	31	14
Once a semester	8	1	18	18	4
Never visited	5	1	6	6	2
No response	1	-	4	-	-
Total	538	100	103	100	100

• Duration of stay in the library

Among the 641 respondents, 35% stayed in the library for less than an hour each time, 51% stayed for 1-2 hours, 13% stayed for 2-4 hours, and 2% stayed for more than 4 hours. Overall, the primary activity participants in the library were students, while faculty generally had shorter stays, mainly for borrowing and returning books.

• Main purposes for visiting the library

Besides providing circulation and reading services, Jinan University Library also regularly holds exhibitions and offers self-study spaces for students. Among the re-

spondents, 85% visited the library to borrow books, approximately 50% to look up information, about 47% to read newspapers and journals, 31% to study, 18% to use the electronic reading room, and 8% to visit various exhibitions.

3) Decomposition and calculation of reader carbon footprint

a) Basic methods for recording carbon footprint

Calculating the carbon footprint is an important and effective way to evaluate greenhouse gas emissions. Currently, the main methods in carbon footprint research are:

- "Bottom-up" model, based on process analysis.
- "Top-down" model, based on input-output analysis. These two methods are established based on the basic principles of life cycle assessment and are known respectively as process analysis and input-output methods.

b) Process analysis method

The process analysis method starts from process analysis, obtaining the input and output data list of the studied object through life cycle inventory analysis, and then calculates the carbon emissions throughout the object's life cycle, i.e., the carbon footprint. The calculation process is as follows:

- Establish the product manufacturing process diagram. By listing the raw materials, activities, and processes involved in the product's entire life cycle, the calculation is facilitated.
- Determine the system boundary. After establishing the product process diagram, it is necessary to define the calculation boundary of the product's carbon footprint. The key principle in defining the system boundary is to include direct and indirect carbon emissions during the production, use, and final disposal of the product.
- Collect data. Calculating the carbon footprint requires collecting two main types of data: all substances and activities related to the product's life cycle; and carbon emission factors, which refer to the amount of carbon dioxide or equivalents emitted per unit of substance. These two types of data can be primary data or secondary data.
- Calculate the carbon footprint. Generally, to calculate the carbon footprint, a mass balance equation is established first to ensure that the input, accumulation, and output of materials are balanced, i.e., Input = Accumulation + Output. Based on the mass balance equation, the carbon emissions of each stage in the product life cycle can be calculated using the basic formula:

$$Ci=\Sigma Qi\times Di \tag{1}$$

In Eq. (1) Ci is the carbon footprint of the product; Qi is the intensity data of the i substance (mass/volume/kilometer/kilowatt-hour); Di is the unit carbon emission factor.

- Verify the results. This step is to verify the accuracy of the carbon footprint calculation results, reduce uncertainty, and improve the credibility of the carbon footprint assessment. Ways to improve result accuracy include: using primary data instead of secondary data; using more accurate secondary data; making the calculation process more realistic and detailed; and having experts review and evaluate the results. [5]

c) Input-output method

The input-output model is a mathematical model that studies the "input" and "output" relationships among various departments within a system. This method, first proposed by the famous American economist Wassily Leontief, is recognized as a currently mature economic analysis method. It can be used to assess the carbon footprint

of industrial sectors, government organizations, enterprises, households, and more. According to the definition of carbon footprint by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), this method divides carbon footprint calculation into three levels:

- Direct carbon emissions from industrial production and transportation processes.
- Expanding the boundary of the first level to include the carbon emissions from energy consumed by industrial sectors (e.g., thermal power, electricity), specifically referring to the entire life cycle carbon emissions of each type of energy production.
- Including the first two levels, referring to all direct and indirect carbon emissions involved in the industrial sector's production chain from cradle to grave. [6]

By comparing the two common carbon footprint measurement methods mentioned above, it is found that the process analysis method obtains the carbon footprint of each link through statistical data on resource and energy consumption throughout the entire process and then aggregates them, which is suitable for recording carbon footprints at the micro level. In contrast, the input-output method emphasizes macro-level carbon emissions, with its results representing the carbon emission levels of a certain industry to a certain extent. The library reader carbon footprint records the carbon emission levels per building unit and is closely related to the library's operating mode and readers' reading methods; therefore, the process analysis method is suitable for measurement.

C. Analysis of Reader Carbon Footprint

Using the process analysis method to record the carbon footprint of reader behavior during library services involves two key steps:

- Defining the system calculation boundary.
- Scientifically collecting data. The parameters and specific measurement methods needed for recording the carbon footprint of reader behavior during library services are provided.

To simplify the measurement process, this project, combined with the requirements of the carbon footprint of reader behavior during library services in Jinan University Library, makes assumptions and simplifies the calculation boundary as follows:

- The carbon emissions brought by various water consumptions in the library are relatively small and are not included in the carbon footprint calculation of this project.
- The carbon dioxide generated during the construction and demolition of library buildings due to resource and energy consumption is related to the construction technology and material selection. According to the analysis results, this part is considered a fixed value and is not included in this calculation.

Based on the above assumptions, the carbon footprint calculation boundary of Jinan University Library is determined:

1) Material boundary

TABLE II. MATERIAL BOUNDARY OF LIBRARY CARBON FOOTPRINT

Electricity Consumption	Lighting, Machine room, Air conditioning, Elevators, Water supply
Natural Gas Consumption	Lithium bromide chiller

2) Time boundary: For the library's carbon footprint, it can be calculated on a daily, monthly, quarterly, or annual cycle. For the reader's carbon footprint, it is calculated from the time the reader enters the library until they leave.

3) Main energy carbon emission factors. The carbon emission factor (emission coefficient) reflects the relationship between energy consumption and carbon emissions. In this project, the main energy consumed is electricity, and the carbon emission factor values are shown in Table III.

TABLE III. MAIN ENERGY CARBON EMISSION FACTORS

Energy Type	Carbon Emission Factor	Source
Electricity/(kgCO2/kWh)	0.7802	National Development and Reform Commission
Natural gas/(kgCO2/kg)	0.444	National Development and Reform Commission
Gasoline/(kgCO2/kg)	0.5538	IPCC National Development and Reform Commission
Diesel/(kgCO2/kg)	0.5921	IPCC National Development and Reform Commission

Based on the above assumptions and simplifications, combined with the conventional design and resource consumption of libraries, and based on the basic principles of the process analysis method, this paper proposes a method for calculating the carbon footprint of libraries:

Energy consumption carbon footprint refers to the carbon emissions generated by the direct consumption of electricity in libraries, generally used for air conditioning, lighting, equipment, etc.

Calculation formula:

$$Ce=\Sigma E\ i\times Di \tag{2}$$

In Eq. (2) Ce is the energy consumption carbon footprint of the library; Ei is the energy consumption of the library, generally including electricity and gas consumption; Di is the carbon emission factor of energy consumption, with different emission factors for different energy forms.

Explanations for energy consumption:

Electricity consumption - This refers to the electricity consumed in public areas, including heating and air conditioning electricity consumption in various reading rooms, public area lighting energy consumption, computer room electricity consumption, etc.

Gas consumption - This mainly includes the gas consumed in kitchens and dining halls, which may also include the gas consumed by lithium bromide chiller units. Each type of gas consumption needs to be measured separately, with separate gas meters set up.

In universities, most of the library readers are faculty and students who mainly walk or ride bicycles to the library. Therefore, this part is not included in the carbon footprint calculation of this project. [7]

With the continuous development of society, the conflict between the environment and energy is becoming increasingly prominent. Libraries shoulder significant social responsibilities and constructing eco-friendly low-carbon libraries is the future trend, necessary for the library's sustainable development, and a concrete manifestation of the library's core values of "people-oriented and environmental resource protection." Therefore, it is necessary to actively advocate and practice the low-carbon operation management mode of libraries, starting from saving water, electricity, and paper, reducing daily work energy consumption and carbon dioxide emissions, and building a low-emission, low-energy consumption, healthy, harmonious, efficient, and sustainable low-carbon library.

3. Strategies for Low-Carbon Library Services

A. Low-Carbon Promotion in Libraries

According to reports, "The UK government proposes to achieve a low-carbon to zero-carbon economy by 2050. Japan is committed to developing low-carbon and zero-carbon technologies, and the US has invested heavily in researching environmentally friendly technologies from biofuels, solar equipment to zero-carbon emission power plants. Countries around the world have quietly begun a race for a low-carbon and zero-carbon society." The low-carbon and zero-carbon economy will greatly improve our living environment. University libraries can carry out various activities such as knowledge competitions, prize quizzes, or use display screens and other media to promote and exhibit within the library, encouraging readers' participation. Universities should first respond to and implement national policies such as waste classification, making readers aware of the importance of low carbon. Libraries can also regularly hold lectures or screen promotional videos about low carbon, inviting authoritative experts to communicate face-to-face with students, spreading low-carbon knowledge, guiding readers to establish a low-carbon lifestyle, and advocating for low-energy, low-consumption, and low-cost living. Utilizing various channels within the library, such as public lectures, to promote low-carbon environmental knowledge, establishing a fixed low-carbon promotion day within the library, letting each reader understand the current environmental situation, changing their mindset, encouraging frugality and the pursuit of a low-carbon life, and enhancing everyone's environmental awareness to truly reduce their carbon footprint in daily life. [8]

B. Low-Carbon Working Methods in Libraries

Library staff should practice "paperless office," reading electronic documents online as much as possible during document circulation, using mobile storage devices to store necessary documents, reducing paper usage. If paper materials are required, double-sided printing or copying should be used to lower carbon emissions and save office expenses. In work communication, electronic mail or instant messaging tools, OA office systems, etc., should be used to transmit files, reducing the use of printers, copiers, and fax machines. Unused electrical equipment in the library should be turned off in time, such as water dispensers, to avoid repeated heating and waste of power. Computers are the most common office tool everywhere; scientifically using computers

can protect the environment, reduce emissions, and extend equipment life. When not in use, computers should be turned off or set to sleep mode. In mild weather, windows should be opened for ventilation, reducing the use of high-power electrical equipment such as air conditioners. When air conditioning is needed, the temperature should be set to a low energy consumption level. Libraries should encourage staff to walk within the library, exercising and saving energy, reducing carbon emissions. Elevators in libraries should primarily be used for transporting books and equipment, setting a good example for readers. [9]

C. Remote Library Services

Libraries, as iconic buildings of universities, are among the most densely populated places on campus. Reducing the frequency and duration of readers' visits can effectively reduce carbon emissions. In the internet era, readers can enjoy various remote services provided by libraries without leaving their homes. Except for certificate processing, book borrowing and returning, and reading paper books and periodicals, which must be done in the library, other services such as literature retrieval, book reservations, loss reporting, and thesis viewing can be completed remotely through internet login. University libraries have large collections of paper books that also have electronic versions, providing convenient conditions for readers to access remotely, reducing the number of visits to the library, saving readers' time, and effectively reducing the library's carbon emissions.

D. Strengthening Library Logistics Management

As public places, libraries gather a large number of readers daily. Various hardware devices in the library, such as air conditioners, elevators, computers, and servers, generate significant carbon emissions during service operations. Therefore, the management of electricity use in the library's logistics department should be strengthened. Combined with the core concept of the low-carbon economy, energy-saving logistics management in university libraries should be achieved by advocating low-carbon behavior among readers and library staff, such as using air conditioning and elevators less, turning off various office equipment and power sources in time, consciously joining the ranks of energy conservation and emission reduction, and changing original working methods and living habits.

E. Supporting Waste Classification

Different types of waste have different disposal methods. Waste classification can not only recycle reusable resources but also avoid pollution problems caused by the mixing of different wastes. It is not difficult to find that waste classification in libraries has not been truly implemented. The waste bins in reading rooms, lounges, and corridors are all large round barrels, making it impossible to classify waste. Therefore, appropriate measures should be taken to achieve waste classification. With classified waste bins in place, as long as readers are aware of the benefits of waste classification, I believe everyone will classify their waste in daily life, greatly reducing waste and lowering carbon emissions.

4. Summary

The "13th Five-Year Plan" for Ecological Environmental Protection clearly proposes to adhere to low-carbon, green, and circular development. As a cultural learning center

of a university, the university library should be constructed through a scientific development concept, standardize readers' behavior through scientific carbon footprint analysis and carbon emission statistics, and provide scientific guidance in management and infrastructure. Low carbon is an attitude towards life and a guiding principle for social development. Only by organically combining the two can cultural confidence be truly implemented.

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