Applied Research on the Modified SIR Model for Information Dissemination in University Library Reading Promotion (Postprint)

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Abstract

[Purpose/Significance] Information dissemination constitutes a crucial component of reading promotion efforts and substantially influences promotion effectiveness. Investigating theoretical models and practical countermeasures for information dissemination in university library reading promotion, grounded in real-world problems, holds significant theoretical and practical importance for expanding information dissemination channels and enhancing reading promotion effectiveness. [Method/Process] This study examines the current state and challenges of information dissemination in university library reading promotion, introduces the SIR model, constructs an improved SIR model by integrating the influence of strong and weak tie theory on information dissemination along with practical considerations, and attempts to apply this improved SIR model to university library reading promotion practice. [Results/Conclusion] The improved SIR model introduces a new variable—secondary infector Io—and a corresponding "promotion medium" role in practice, transforming the original single weak-tie information dissemination into a composite process comprising one weak-tie and two strong-tie information dissemination events, which can effectively enhance information dissemination efficiency in reading promotion and provide theoretical guidance for practical implementation.

Full Text

Research on the Application of an Improved SIR Model to Information Dissemination in University Library Reading Promotion

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Abstract:
[**Purpose/Significance**] Information dissemination constitutes a critical component of reading promotion work and significantly influences its effectiveness. Grounded in practical problems, exploring theoretical models and practical strategies for information dissemination in university library reading promotion holds important theoretical and practical significance for broadening information dissemination channels and enhancing reading promotion outcomes. [**Method/Process**] This study examines the current state and problems of information dissemination in university library reading promotion, introduces the SIR model, constructs an improved SIR model incorporating the influence of strong and weak tie theory on information dissemination along with practical issues, and attempts to apply the improved SIR model to university library reading promotion practice. [**Result/Conclusion**] The improved SIR model introduces a new variable—secondary infector I—and a corresponding "promotion medium" role in practice, transforming the original single weak-tie information transmission into a combination of one weak-tie and two strong-tie information transmissions, which can effectively improve information dissemination efficiency in reading promotion and provide theoretical reference for practical work.

Keywords: SIR model; information dissemination; strong ties; weak ties; reading promotion
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Reading promotion has emerged as an increasingly important service in libraries, attracting considerable scholarly attention. Researchers have defined this concept from various perspectives: Fan Bingsi views library reading promotion in China as an umbrella term for library marketing and new reading services, encompassing all library services that promote reading, literacy, lifelong learning, or informal education, particularly novel, activity-based services [1]. Wang Bo defines reading promotion as activities through which libraries guide reader attention from vast collections to a curated selection of attractive resources via careful planning and creativity, thereby improving collection circulation and utilization [2]. Zhang Huaitao considers reading promotion as activities undertaken by social organizations or individuals to encourage reading, essentially popularizing reading activities beneficial to individuals and society [3]. These definitions reveal two core components: reading activities themselves and promotion methods. The latter—how to disseminate reading-related content to readers—essentially concerns information transmission between promotion subjects and objects. Unimpeded information dissemination channels constitute the fundamental prerequisite for effective reading promotion; without reaching readers, even the most perfect reading promotion content becomes a solo performance by organizers. Therefore, this study focuses on information dissemination in university library reading promotion, attempting to introduce the SIR

(Susceptible-Infected-Removed) model and, integrating strong and weak tie theory with the characteristics of reading promotion information dissemination, improve the SIR model and apply it to university library reading promotion practice to solve information dissemination challenges.

2. Analysis of the Current State of Information Dissemination in University Library Reading Promotion

Drawing on Lasswell' s "5W" communication model, we analyze the current state of information dissemination in university library reading promotion. The "5W" model classically describes the basic elements and process of information communication: Who, Says What, In Which Channel, To Whom, and With What Effect [4]. The reading promotion information dissemination model based on the "5W" framework is illustrated in Figure 1 [Figure 1: see original paper].

As shown in Figure 1, the information dissemination subject is the library; the objects are all university readers, representing broad recipients; and the dissemination methods and content involve information transmission selected by the information center. Using the elements of this model as entry points, this study conducts empirical research on Dalian University of Technology Library, analyzing the current state of information dissemination in university library reading promotion based on tracking surveys, data analysis, and reader feedback on reading promotion information dissemination from March 2019 to January 2020 (one academic year). Empirical data derive from three sources: (1) a questionnaire survey of Dalian University of Technology readers using sampling, focusing on information dissemination throughout the year' s reading promotion activities (200 questionnaires distributed, 200 returned, 198 valid); (2) feedback and tracking data from reading promotion activity participants, including information acquisition channels and methods; and (3) statistical analysis of reading promotion information dissemination through web pages and new media platforms. Based on these data, several problems emerge in current university library reading promotion information dissemination:

(1) Single-subject to broad-object transmission. Current dissemination follows a point-to-surface pattern from a single subject to extensive objects. The limited radiation range of the subject leads to decreased information coverage, leaving many objects outside the dissemination scope. For instance, Dalian University of Technology Library conducted over 50 reading clubs, lectures, resource recommendations, interactive experiences, exhibitions, and other activities annually. However, a survey of all readers revealed that 48.5% received related information only 6–15 times per year (the largest proportion), 27% received information 16–25 times, 14.8% received information fewer than 5 times, and only 9.7% received information more than 26 times. As a single dissemination subject facing over 40,000 faculty and student readers, university libraries struggle to achieve full information coverage.

(2) Limited dissemination channels. Current channels primarily include

field-based dissemination (posters, electronic screens within the library) and network-based dissemination (WeChat platforms, web pages). Both approaches have limitations: objects closely connected to library spaces or network carriers receive information more easily, while others remain in "blind spots," resulting in small coverage. The questionnaire survey shows a strong non-linear correlation between reading promotion information reception and library visit frequency —higher visit rates correlate with greater attention to library information and higher reception rates. Among readers receiving information 15–26 times or more than 26 times annually, 70.6% visited the library more than 3 times per week on average, and 82.4% followed the library' s official WeChat account. Conversely, among those receiving information fewer than 5 times, 58% visited the library fewer than 3 times per week (23.8% visited less than once per week), and nearly half did not follow the official WeChat account. Thus, university library reading promotion information dissemination channels face spatial and carrier-specific constraints.

(3) Low information diffusion and forwarding rates. The absence of specific information-forwarding groups results in extremely low forwarding rates. Taking network media dissemination as an example, the primary channel is the official WeChat platform. As of January 2020, Dalian University of Technology' s official platform had 43,758 users. Excluding external users, valid on-campus readers (determined by student ID binding, as most on-campus readers bind their library cards for mobile services while external readers cannot) numbered 23,075, accounting for 53% of total student enrollment (43,519). While information sent through the WeChat platform could reach every valid user, achieving a 53% delivery rate, the effective dissemination rate measured by click-through rates averaged less than 11% of the delivery rate (less than 7% of total readers), and forwarding volume accounted for only 3% of clicks, indicating extremely low secondary dissemination rates. Tracking surveys of participants in reading promotion activities throughout the year revealed that 92.1% obtained information directly from the library, while only 7.9% received it through secondary dissemination. Survey results showed that 68.3% of readers preferred obtaining library and reading promotion information from acquaintances (classmates, teachers) rather than from the library itself. Consequently, university library reading promotion information lacks a complete dissemination chain and secondary or multiple dissemination diffusion.

3. Application of the Improved SIR Model to Information Dissemination in University Library Reading Promotion

3.1. Applicability of the SIR Model to Reading Promotion Information Dissemination

The SIR model was first proposed by D. Bernoulli in 1760 in a paper on smallpox inoculation [5]. Mathematical modeling of infectious diseases emerged in the early 20th century. In 1906, W. H. Hamer constructed a discrete-time

mathematical model to study recurrent measles epidemics [6]. In 1927, W. O. Kermack and A. G. McKendrick proposed the SIR compartmental model to study the London Black Death and Bombay plague [7]. The SIR model divides the total population into three categories: S (Susceptible), uninfected individuals who can be infected; I (Infective), infected individuals with contagiousness; and R (Removal), isolated or immune individuals. The mutual transformations among these three categories are illustrated in Figure 2 [Figure 2: see original paper]. Assuming a total population of N, such that $S(t) + R(t) + I(t) = N$, calculations generally use a unit of 1. Assuming an infection rate λ (the probability of susceptible individuals being infected after contact with infectives) and an immunity rate β (the probability of infectives gaining immunity), the dynamic differential equations describing the evolution and relationships among these groups are as follows:

$$\frac{ds(t)}{dt} = -\lambda s(t)i(t)$$

$$\frac{di(t)}{dt} = \lambda s(t)i(t) - \beta(t)$$

$$\frac{dr(t)}{dt} = \beta i(t)$$

where $s(t) + r(t) + i(t) = 1$.

Recent SIR model research has primarily focused on biological virus transmission, with emerging applications in information science and economic management. Wang Daoping and Li Miao [8] used the SIR model to study knowledge transfer in supply chain knowledge service networks, identifying transmission and immunity rates as the main influencing factors. Wei Jing, Huang Yangjianghao, and Lin Ping et al. [9] analyzed influencing factors of an improved SIR model for public opinion dissemination on Weibo networks, proposing theoretically effective recommendations for controlling public opinion spread from an immunity perspective. Yao Jingjing, Jiang Liang, and Yao Hongxing [10] studied emotional information dissemination using the SIR model, proposing that emotional information bias constitutes an important factor causing cross-propagation of emotional information. Zhang Huimin and Sun Guoqiang [11] analyzed risk transmission processes in enterprise networks under the internet economy using the SIR model, verifying simulation results through model derivation. These studies provide valuable references for applying the SIR model to analyze information dissemination in university library reading promotion.

University library reading promotion information dissemination shares notable similarities with infectious disease transmission:

(1) Similar transmission agents. Infectious diseases spread through viruses, which exhibit diversity in type, transmissibility, pathogenicity, harmfulness, and

transmission speed. Reading promotion disseminates information, which similarly possesses abstract and invisible qualities, with diverse types differing in dissemination breadth, speed, and importance.

(2) Similar transmission nodes. Infectious diseases primarily target humans as transmission objects and nodes. Since individuals have different antibodies and resistance levels, and varying activity levels and movement patterns, transmission scope and objects among multiple nodes exhibit differences and uncertainties. Reading promotion information dissemination also involves humans as objects and nodes. Since individuals have different interests and recognition levels regarding information, with varying probabilities and degrees of acceptance, transmission scope and objects among different nodes similarly exhibit differences and uncertainties, influenced by activity levels, movement patterns, and audience interest.

(3) Similar transmission pathways. Infectious disease transmission requires contact, spreading through direct contact between nodes or diffusing to new groups. Beyond immunity effects, closer contact with infected individuals increases infection probability. Information dissemination also requires contact, including direct and network contact. Beyond information attractiveness, closer contact and interaction with disseminators through various networks and realities increases acceptance probability.

In summary, university library reading promotion information dissemination demonstrates high theoretical similarity with infectious disease transmission, making the SIR model highly applicable for analyzing reading promotion information dissemination. This study introduces the SIR model and improves it based on strong and weak tie theory to more precisely analyze reading promotion information dissemination characteristics and patterns, thereby achieving the goal of expanding reading promotion information dissemination.

3.2. Application of the SIR Model to Reading Promotion Information Dissemination

Applying the SIR model to university library reading promotion information dissemination defines the information dissemination subject (library) as infector I, and information dissemination objects as two types: susceptible individuals S, who interact with and provide feedback on received information and can become new disseminators; and removed individuals R, who lack interest and interaction with information and no longer disseminate it. The interactions and evolution patterns among these three groups roughly follow the dynamic differential equations and transformation model in Figure 2. While the SIR model abstractly represents the reading promotion information dissemination process, university reading promotion information dissemination exhibits distinctive features that the standard SIR model cannot fully capture:

(1) Reverse dissemination purpose. Infectious disease research aims to suppress virus spread, whereas reading promotion information dissemination seeks

to identify transmission patterns to expand information dissemination scope and efficiency. Unlike event-based information dissemination in social networks like Weibo or WeChat, university reading promotion information constitutes practical information that rarely experiences fermentation, deterioration, or public opinion orientation issues during transmission. Therefore, the fundamental goal of university reading promotion information dissemination is enabling more readers to receive reading promotion information, thereby achieving reading promotion objectives.

(2) Time-sensitive and time-limited dissemination. Reading promotion information is generally time-sensitive, with dissemination periods ranging from information release to activity conclusion. Beyond this timeframe, dissemination loses significance. While some resource recommendations remain valid long-term, they still face timeliness issues—untimely dissemination causes information accumulation and affects recommendation effectiveness. Thus, reading promotion information dissemination is time-sensitive rather than unlimited.

(3) Specificity of the primary dissemination subject. During initial dissemination, only one information dissemination subject exists: the library itself. With relatively fixed dissemination time t, achieving large-scale, high-efficiency dissemination requires increasing the infection rate λ and reducing the immunity rate β on one hand, and increasing secondary dissemination subjects and improving secondary dissemination rates on the other.

Max Weber posited that human essence constitutes the sum total of social relationships. University reading promotion information dissemination essentially involves communication and exchange among people within the campus relationship network. Based on this analysis, this study introduces strong and weak tie theory to improve the SIR model for more precise analysis of reading promotion information dissemination characteristics and patterns, thereby achieving the goal of expanding reading promotion information dissemination.

3.3. Improved SIR Model Based on Strong and Weak Tie Theory and Its Application to Reading Promotion Information Dissemination

Strong and weak tie theory posits that interpersonal connections vary in strength, measured across four dimensions: interaction frequency, emotional intensity, intimacy, and reciprocal exchange. Relationships are classified as strong or weak ties. Weak ties provide extensive information with broad dissemination scope but low quality, while strong ties offer high-quality, credible information transmission but limited scope. Both simultaneously provide information breadth and depth.

Introducing this theory into the SIR model adds two potential influencing factors: infection intensity P and infection scope Q. Under strong-tie conditions, each infector' s infection scope Q is relatively small within time t after disease outbreak, resulting in fewer infected individuals per unit time, but high infection intensity P yields a high infection rate λ and low immunity rate β. Conversely,

under weak-tie conditions, infection scope Q is relatively large, but low infection intensity P results in a low infection rate λ and high immunity rate β.

Based on strong and weak tie theory and the characteristics of university reading promotion information dissemination, this study improves the SIR model with the goal of expanding information dissemination. A new variable I is introduced between infector I and susceptible individuals S as a secondary or sub-infector, serving as a medium between I and S. Once information is disseminated, sub-infectors I directly and secondarily infect susceptible individuals. Based on the above analysis, initial reading promotion information dissemination in universities involves only one dissemination subject—the library as infector I—with weak ties between I and readers, lacking complete and solid dissemination chains. This constitutes the key problem in information dissemination. In the improved SIR model, I supplements infector I in information transmission. I should first establish strong ties with infector I within established social networks through certain methods and rules, becoming fixed infectees of I with an extremely low probability β_1 of transitioning to R. Additionally, each I should maintain strong ties with some susceptible individuals S within existing social networks. This ensures that, on one hand, strong ties between sub-infectors and susceptible individuals guarantee high infection intensity P and improved infection rate λ; on the other hand, increasing initial infector numbers—from primary infector I to multiple sub-infectors I—simultaneously transmitting information also ensures infection scope Q. The key innovation of the new model lies in transforming single weak-tie information dissemination into the sum of one weak-tie and two strong-tie information transmissions within existing social networks. The improved SIR model is illustrated in Figure 3 [Figure 3: see original paper].

The evolution patterns of various groups and the increased infection rate model based on the improved SIR model are expressed as:

$$\begin{aligned}
\frac{ds(t)}{dt} &= -\lambda_2(t)i(t) - \lambda_1(t)i_o(t) \\
\frac{di_o(t)}{dt} &= \lambda_1 s(t)i_o(t) - \beta_1 i_o(t) \\
\frac{di(t)}{dt} &= \lambda_2 s(t)i(t) - \beta_2 i(t) \\
\frac{dr(t)}{dt} &= \beta_2 i(t) + \beta_1 i_o(t)
\end{aligned}$$

where $s(t) + r(t) + i_o(t) + i(t) = 1$.

In summary, traditional information dissemination pathways lack fixed reception points and important re-dissemination nodes and subjects. Information spreads directly from one point to multiple surfaces in a divergent form, with weak ties between the point and surfaces, as illustrated in Figure 4 [Figure 4: see original paper].

In information dissemination based on the improved SIR model, information exhibits two diffusion patterns upon release: (1) point-to-point directional dissemination—from infector (library) I to sub-infector (promotion medium) I , followed by point-to-multipoint dissemination from sub-infector (promotion medium) I to susceptible individuals (ordinary readers) S; and (2) original point-to-surface dissemination occurring simultaneously, where the subject directly disseminates to objects—from infector (library) I directly to susceptible individuals (ordinary readers) S. Reading promotion information dissemination based on the improved SIR model is illustrated in Figure 5 [Figure 5: see original paper].

4. Practical Application of the Improved SIR Model in University Library Reading Promotion

4.1. Introducing Promotion Media to Form a Multi-Subject Collaborative Information Dissemination System

Applying the improved SIR model to university library reading promotion practice involves introducing the element of "promotion medium." While sharing some similarities with "reading promotion persons" in existing library research, promotion media differ fundamentally in composition and responsibilities. In terms of composition, promotion media should be organizations rather than individuals, as organizations possess stability and continuity, enabling standardized management and constraint through systems, with functions and responsibilities unaffected by personnel turnover. Functionally and goal-wise, promotion media primarily bear responsibility for information dissemination between libraries and readers, serving as an extension of information dissemination channels. According to the responsibilities and improved SIR model, promotion media should first be student organizations or groups closest to readers, maintaining the most direct and close connections (strong-tie relationships). Second, promotion media should be widely and evenly distributed across departments and grades to ensure coverage. Finally, they should play functional roles in specific groups, possessing certain reading promotion information dissemination foundations and establishing strong ties with libraries through existing organizational management models, institutional requirements, and work willingness. Consequently, promotion media can be selected from existing relevant student societies and student union or youth league organizations, particularly cultural student organizations and societies with interest and foundational work in reading promotion. University libraries should use promotion media as a pathway to establish connections with various campus departments and schools, uniting campus forces to form a multi-collaborative reading promotion information dissemination subject that leverages respective advantages. As a supplementary force to the library as promotion subject, promotion media also serve as an information bridge between promotion subjects and objects, solving the dilemma of one subject disseminating information to all readers and creating a new situation where multiple subjects simultaneously disseminate reading promotion information to readers, thereby expanding information dissemination coverage

and influence.

4.2. Utilizing Multiple Information Carriers to Enrich Dissemination Methods

Contemporary university students increasingly access information through diverse channels and formats, including WeChat, Weibo, TikTok, Bilibili, and other platforms featuring text, graphics, animations, audio, video, and other multimedia forms. These promotion methods are gradually accepted and favored by today' s university students. Therefore, reading promotion information dissemination methods must be inclusive and diversified, fully leveraging multiple media formats to enhance information attractiveness and dissemination capacity. On one hand, the improved SIR model transforms single weak-tie information dissemination into the sum of one weak-tie and two strong-tie transmissions, aiming to increase secondary and multiple dissemination probabilities. In university library reading promotion practice, information should be disseminated through carriers that facilitate easy transmission and diffusion, such as WeChat, Weibo, TikTok, and other network platforms that students can easily access and share, while reducing traditional field-based methods constrained by space that are less likely to generate multiple disseminations. On the other hand, information should be packaged in diverse formats including text, graphics, audio, and video to make presentation more attractive, as recognized information is more likely to be widely disseminated.

4.3. Innovating Reading Promotion Models to Improve Information Quality

Content attractiveness constitutes another critical factor influencing widespread dissemination. Primary dissemination of reading promotion activities occurs from dissemination subjects and media to objects, constrained by dissemination mechanisms, subjects, and channels, representing a fixed transmission under specific mechanisms. However, secondary and multiple disseminations occur primarily between objects, representing completely spontaneous transmission that depends on whether readers recognize information content. Once considered valuable, readers actively disseminate information to others, generating broad dissemination effects. Consequently, university library reading promotion activities have gradually diversified and enriched in recent years. Universities have enhanced the attractive connotations of reading promotion activities through innovative formats, integrating reading, writing, singing, drawing, and performing into activities. Examples include Peking University' s "Reading Marathon," Shanghai Jiao Tong University' s "Living Library," Tianjin University of Finance and Economics' campus drama competition, Sichuan University' s micro-film e-book project, Dalian University of Technology Library' s traditional cultural interactive experience activities, and Wuhan University' s "Save Little Bu" game-based reading promotion. All have achieved excellent results by increasing the attractive content of reading promotion information, strengthening its

disseminability, and expanding the breadth of reading promotion information dissemination.

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Author Contributions:
Zhao Ourong: Responsible for literature compilation and providing revision suggestions;
Ma Wenfei: Responsible for overall research framework and writing the paper;
Han Fang: Responsible for data collection, processing, and analysis.

Note: This study analyzed the current state and problems of information dissemination in university library reading promotion based on empirical research conducted at Dalian University of Technology Library. While the findings reflect the status and issues of information dissemination in reading promotion at Dalian University of Technology Library and may partially represent similar issues at other university libraries, they cannot represent all university libraries. Applying this theoretical model to reading promotion information dissemination requires adjustment and improvement based on specific problems and practical work.

Note: Figure translations are in progress. See original paper for figures.