Origin, Evolutionary Trends, and Connotations of the Safety Intelligence Concept: A Theoretical Examination from the Perspective of Safety Science (Postprint)

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Abstract

[Purpose/Significance] Safety issues are currently a significant practical issue of widespread concern among the nation, government, enterprises, society, the public, and academia, and safety intelligence is an essential tool for ensuring safety; therefore, research on safety intelligence holds significant theoretical and practical significance. [Method/Process] Using literature analysis and speculative methods, and from the perspective of safety science theory, this study demonstrates the necessity, importance, and urgency of interpreting and defining the concept of safety intelligence from a safety science viewpoint, discusses the origin and evolution trends of the safety intelligence concept, and analyzes the connotation of safety intelligence. [Results/Conclusions] From the perspective of safety science theory, the new understanding of safety management from safety information to safety intelligence constitutes the fundamental driving force for proposing the concept of safety intelligence, and the overall evolution trend of the safety intelligence concept is from dispersed to unified. Meanwhile, from the perspective of system safety science, safety intelligence refers to all safety information that affects system safety behavior.

Full Text

The Origin, Evolution Trends, and Meaning of Safety & Security-Related Intelligence: A Speculation from the Perspective of Safety & Security Science

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Abstract: [Purpose/Significance] Safety and security issues represent a critical practical concern for states, governments, enterprises, society, the public, and academia. Safety & security-related intelligence (SI) serves as an essential asset for ensuring safety and security, making research on SI profoundly significant both theoretically and practically. [Method/Process] Employing literature analysis and speculative methods from the perspective of safety & security science, this article demonstrates the necessity, importance, and urgency of interpreting and defining the SI concept through a safety science lens, explores the origin and evolution trends of SI, and analyzes its meaning. [Result/Conclusion] From a safety science perspective, the fundamental driver for proposing the SI concept is the new understanding of safety management that transitions from safety information to safety intelligence, with the overall evolution trend of the SI concept moving from fragmentation to unity. Moreover, from a system safety science perspective, safety intelligence refers to all safety-related information that influences system safety behavior.

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1. Problem Statement

Since humanity entered the risk society, safety issues have become a focal point of concern. Particularly, contemporary Chinese society is in a transitional period characterized by intensifying contradictions and increasing safety crises and risks. Concurrently, China is undergoing continuous industrialization and urbanization, with various artificial systems (such as cities) becoming increasingly large-scale and complex, production and operation scales expanding daily, and various safety risks growing dramatically. These risks exhibit trends of overlapping interaction and emergent properties, while traditional and non-traditional safety issues intertwine, posing numerous challenges to safety management (or "safety governance") [1-2]. In fact, nations worldwide face similarly severe safety situations and new challenges [3]. Consequently, safety issues have become an important practical problem widely concerned by states, governments, enterprises, society, the public, and academia. For this reason, Safety & Security Science (3S), as a discipline studying safety promotion theories and methods, has experienced rapid development and growth over the past one to two decades, establishing itself as an independent disciplinary field and an emerging discipline with great potential [2-3].

Safety science is a typical highly interdisciplinary and comprehensive field [2-3]. This characteristic determines that scholars from other disciplines can examine and conduct research on safety issues from their own disciplinary perspectives, particularly engaging in interdisciplinary research between intelligence science and safety science [2]. Intelligence science is a discipline aimed at providing intelligence services for management (especially decision-making), with a long history

that has extensively permeated various disciplinary fields, including safety science [4-5]. Chinese intelligence scholar Bao Changhuo [5] explicitly pointed out that intelligence science should pay greater attention to major events, threats, and crises, focusing on their analysis, warning, advocacy, and planning. Indeed, in recent years, examining and studying safety issues from an intelligence perspective, or conducting interdisciplinary research between intelligence science and safety science, has garnered widespread academic attention and produced a series of representative research achievements (e.g., [1, 7-10]). Consequently, safety intelligence (such as national security intelligence [7-8], military security intelligence [9], public safety intelligence [9-10], information security intelligence [11], and emergency intelligence [1]) has become the next important new research area and frontier in intelligence science following scientific and technological intelligence and competitive intelligence. In fact, the connection between intelligence science and safety science has long existed, with the intelligence concept entering the safety domain early on (or rather, the intelligence concept originated earliest in the safety science field). Why can we say this? The concept of intelligence has ancient origins, traceable to "military intelligence (including military security intelligence)," "national security intelligence," and "public security intelligence (or 'police intelligence,' which involves numerous public safety intelligence)" [4-5]. This is also an important reason why people first associate intelligence closely with military security and national security. Moreover, from another perspective, safety intelligence is a product of human safety needs and is ancient in origin. Since the emergence of humanity, humans have pursued safety, simultaneously generating demand for safety intelligence driven by safety needs. The ultimate goal of human pursuit of safety needs is "preventing problems before they occur," making safety intelligence activities a natural emergence.

Literature review reveals that research specifically focusing on Safety & Security-Related Intelligence (SI) remains relatively rare, with current studies exhibiting three main characteristics: First, research primarily concentrates on the Security domain (such as national security [7-8], military security [9], technological security [12], and information security [11]), with some studies in the Security & Safety intersection (such as public safety [9-10] and urban safety [13]), but research in the pure Safety domain is extremely rare (with only explorations in disaster intelligence [14]). Second, research is scattered across specific safety domains (such as national security [7-8], military security [9], and public safety [9-10]) or specific safety management links (such as emergency management [1, 13]), with rare research findings addressing overall safety (or "comprehensive safety") and the entire safety management process. Third, researchers are mainly concentrated in intelligence science and public management disciplines, with virtually no scholars from the safety science field conducting SI research, resulting in a lack of SI research from a safety science perspective. These three characteristics will be discussed in detail below.

The above analysis indicates that current SI research is fragmented, operating in isolation without unified norms and guidance, leading to inconsistent under-

standing, comprehension, and definition of the SI concept across different fields. This not only results in a lack of holistic grasp and understanding of the SI concept but also creates barriers and difficulties for academic exchange on SI among scholars from different domains. Concepts represent both the induction and refinement of past understanding and the starting point for new understanding (in short, concepts are the logical starting point and basic unit for correct understanding). Therefore, the primary task in SI research should be clarifying the concept of "safety intelligence." The author believes that safety science researchers should shoulder the responsibility of unifying the SI concept for the following reasons:

(1) Safety intelligence is a concept derived directly from the intersection of intelligence science and safety science, representing a combination of the most basic concept "safety" from the safety science field and the most basic concept "intelligence" from the intelligence science field. This shows that we need to interpret the SI concept not only from an intelligence science perspective but also from a safety science perspective; both disciplinary perspectives are indispensable. Currently, interpretation and research of SI from a safety science perspective are lacking and urgently need supplementation. Furthermore, intelligence science and safety science share a commonality: both involve extremely broad scopes and extensive content [2, 4-5]. Complementary research on SI between these two disciplines will further enrich and deepen SI research.

(2) Researchers from other disciplines generally study specific safety problems in particular domains or specific links in safety management based solely on an intelligence science perspective [1, 7-12]. However, safety science today emphasizes a system safety research paradigm, focusing on all factors affecting system safety from a holistic perspective [3, 15], and safety science researchers generally possess rich practical knowledge and experience in safety science research. Therefore, comparatively speaking, safety science researchers are more capable of understanding and interpreting the SI concept from an overall perspective, thereby achieving the important goal of unifying the SI concept.

(3) Safety intelligence is an emerging marginal field at the intersection of intelligence science and safety science. For the intelligence science field, judging from the widespread attention to SI research in recent years, SI may no longer be a new concept and is being increasingly understood, accepted, and concerned by more intelligence researchers. However, regrettably, it remains a relatively unfamiliar concept in the safety field, which also indicates its great appeal in the safety domain. Explorations and research on SI by intelligence science researchers will undoubtedly enlighten safety science researchers and prompt them to develop new research ideas and open new research paths in the safety field. Therefore, safety science researchers must understand, recognize, and accept the SI concept and conduct further in-depth research and exploration based on

the beneficial explorations and studies by intelligence science researchers.

(4) In recent years, organizations (such as government departments and enterprises) have vigorously carried out safety management informatization (referred to as "safety informatization") and have successively built various supporting safety information systems and platforms [15]. However, numerous deficiencies remain in SI work in safety management practice [1, 15-16], mainly manifested in three aspects: First, vague understanding of SI in safety management, with recognition of safety management still remaining at the "safety information" level (to be discussed in detail below), and insufficient intelligence capabilities among safety management participants. Second, the SI network for safety management is not yet smooth (safety management information systems cannot interconnect), making system collaboration and SI sharing difficult. Third, intelligence professionals (including professional intelligence agencies) have not yet been well integrated into the safety field' s intelligence network, with insufficient expansion and penetration of intelligence work in the safety domain, and inadequate recognition and attention from the safety management field.

In summary, safety intelligence represents a "rich mine" in both safety science and intelligence science, with enormous untapped potential. Intelligence science researchers have taken the lead in mining it, and their work eagerly awaits participation from safety science researchers. Currently, specialized SI research oriented toward safety science (particularly safety management) is lacking, necessitating SI research from a safety science perspective. The primary task is to understand and define the SI concept from a safety science angle, which is certainly what all rational SI researchers anticipate. As safety researchers, the authors have gradually realized the urgency, importance, and necessity of conducting SI research through long-term exploration in safety informatics, particularly when reflecting on current safety informatics research and practice. Therefore, based on existing SI research, this article employs literature analysis and speculative methods to explore the origin, evolution, and new connotations of the SI concept from a safety science perspective, aiming to provide a powerful supplement to previous deficiencies in SI research and offer new ideas for subsequent SI studies.

2. The Origin of the Safety Intelligence Concept

Regarding the origin of the "safety intelligence" concept, it should be a typical product of introducing the "intelligence"concept and applying intelligence science theories and methods to the safety science field. As an academic concept at the intersection of intelligence science and safety science, the SI concept originates from new understandings of safety science (particularly safety management) from an intelligence science perspective, namely the transition "from safety information to safety intelligence" in safety management.

The phenomenon of safety information deficiency (or incomplete safety infor-

mation or safety information asymmetry) widely exists in safety management work and represents the fundamental cause of safety management failures—a new understanding and consensus reached in recent years among safety science academia and practitioners [6, 15, 17-19]. Wang Bing and Wu Chao [15] argue: "Safety information is the necessary road to safety & security (The road to safety & security must pass through safety & security-related information)." The most meaningful and best method for safety management is to utilize optimal safety information to conduct safety management work. How safety information is collected, managed, and used determines the success or failure of safety management [17]. In recent years, a new safety management concept and method has been actively advocated and practiced in the safety field: Evidence-Based Safety & Security (EBS) (based on evidence management) [17], aiming to effectively solve the safety information deficiency dilemma in safety management. From an intelligence perspective, the "evidence" in evidence-based safety management is essentially safety information, or more strictly and accurately, safety intelligence [19]. Regarding management, "intelligence is all information (or content) that affects management (mainly management decision-making)" [20]. Based on this understanding and Wang Bing and Wu Chao' s recognition of the essence of "evidence" in evidence-based safety management [19], from an intelligence perspective, the aforementioned "safety information" (i.e., "safety information" affecting safety management) actually refers to "safety intelligence" ("safety information" and "safety intelligence" should not be confused; their difference and connection are similar to that between "information" and "intelligence," which will not be elaborated due to space limitations). This is because, according to intelligence transformation theory [21], safety information is originally "objective," "infinite," and "useless," whereas safety intelligence is service-oriented for safety management and directly affects safety management. From this perspective, what is truly missing in safety management is "safety intelligence" rather than "safety information." For example, the 1995 Kobe earthquake in Japan resulted in poor disaster relief due to delayed disaster intelligence [22]; the 2003 SARS outbreak in China, the "7·23" Yong-Wen railway major accident in 2011, the "11·22" Sinopec oil pipeline leak and explosion in Qingdao in 2013, and the "8·12" Tianjin Binhai New Area explosion in 2015 were all closely related to SI analysis errors, untimely SI transmission, or SI failure [16].

From an intelligence perspective, safety management should be an upgrading and progressive process of the "safety information chain." It is generally believed that the information chain consists of six key elements: "Facts → Data → Information → Knowledge → Intelligence → Wisdom" [23]. Regarding the elements of the safety information chain, safety scholars (such as Huang et al. [24]) have made similar descriptions to those of the information chain elements, with its upstream facing physical attributes and its downstream facing cognitive attributes [4]. According to the information (safety information) chain principle, safety information mostly occupies the lower level of the safety information chain with "eyes looking downward," while safety intelligence resides at the higher level of the safety information chain and should be more "eyes looking upward"

toward safety management [1, 13]. Therefore, for safety management, safety information is originally "useless"; only when safety information (including safety knowledge) is "activated" and transformed into safety intelligence can it influence and support safety management (i.e., play an effective role). In short, safety management without safety intelligence is like water without a source.

From the information chain theory, "intelligence-ization" is the foundation and prerequisite for achieving "intelligent (smart)-ization." If people's understanding remains at the "safety information" level of the safety information chain, the ultimate goal of "smart (intelligent) safety" pursued by safety management informatization (referred to as "safety informatization") will become "impossible to discuss" and "out of reach." Currently, states, governments, societies, cities, and enterprises have established various safety databases or safety information systems and platforms, but they still fail to play ideal roles in actual safety management. The main reason is that safety researchers and practitioners have not truly comprehended the difference between "safety information" and "safety intelligence," causing their understanding and work focus to remain at the "safety information" level without ascending to the "safety intelligence" level, and failing to elevate safety information to safety intelligence to serve safety management. Obviously, such cognitive and research practice drawbacks will seriously hinder the safety informatization process and the effective exertion of its utility, also causing safety informatization practice to become merely "safety data (information) repositories," or even "empty shells" and dispensable "decorations" or "vases." Specifically, although remarkable achievements have been made in safety information resource construction, the problem of "emphasizing collection over utilization" has long existed and become increasingly prominent. Large-scale safety information resource libraries cannot quickly and effectively serve the resolution of specific safety problems, meaning the resource-oriented thinking of safety intelligence remains severe, with limited effectiveness and insufficient motivation for long-term service to safety management [25]. In summary, safety intelligence is the support and key essential element of safety management.

Examining the role of safety intelligence from the perspective of safety managers is crucial. According to B.C. Brookes' knowledge equation, "$K(S) + \Delta I = K[S + \Delta S]$, where $K(S)$ is the original knowledge structure, ΔI is the amount of intelligence absorbed, and $K[S + \Delta S]$ is the final knowledge structure" [26], we can also explain that safety intelligence enables a "qualitative" improvement in safety management quality. Regarding safety management, according to Brookes' knowledge equation and from the perspective of safety managers (subjects), $K(S)$ represents safety managers' original safety knowledge structure, ΔI represents safety knowledge proliferated through absorbing safety intelligence (with safety information as the subject), and $K[S + \Delta S]$ refers to safety managers' safety knowledge structure under the support of safety intelligence. In this situation, theoretically, safety managers' safety management behaviors will become more reliable, scientific, and correct.

As safety issues become increasingly complex and intertwined, particularly with

the widespread application of new technologies such as the Internet of Things, cloud computing, and mobile Internet in the safety field, safety information volume is growing explosively, ushering in the era of big data in safety. In this context, the role and significance of safety intelligence have not diminished but rather become more prominent, highlighting the problem of "useless safety information flooding while valuable safety intelligence is missing," which seriously affects the predictive, decision-making, and execution power of safety management. This mainly includes three reasons: First, most safety informatization work remains only at the safety information level, causing it to remain outside safety intelligence work. Second, safety researchers and practitioners lack strong intelligence awareness and have vague understanding and positioning of safety intelligence, leading to intelligence oversight. Third, safety professionals have limited intelligence analysis capabilities, while intelligence professionals (including professional intelligence service agencies) have not been well integrated into the safety field and have not cooperated well with safety professionals to provide SI services, resulting in problems such as low-quality and poor-timeliness SI products.

In summary, only when safety researchers and practitioners elevate safety information to the level of safety intelligence from all dimensions of safety management, only when safety intelligence is extracted during safety management processes, and only when the "principal contradiction" in safety management —sublimating safety information (data) into safety intelligence resources with safety management utility—is grasped, can the predictive, explanatory, and supporting power of safety information (including safety intelligence) for safety management become more significant, making it easier to achieve a safety management system dominated by and centered on safety intelligence. Obviously, the "safety intelligence-safety management" oriented research and practice paradigm for safety management is essentially an innovation and transformation of safety management research and practice paradigms. However, currently, safety intelligence work in safety management still faces many deficiencies and confusions. Therefore, the focus of safety management urgently needs to upgrade from "universal safety variables (safety information)" to "targeted safety variables (safety intelligence)," which represents the key difficulty in safety management from an intelligence perspective. In recent years, in the safety science field, particularly in the Security domain (such as military security [9], national security [7-8], technological security [12], information security [11], and public safety [9]), safety intelligence (here specifically referring to Security-Related Intelligence) has received widespread attention, and a series of highly theoretically and practically significant research and practical explorations have been conducted, opening a good beginning for the successful transition from safety information to safety intelligence and for further deepening the understanding, research, and practice of safety intelligence. Currently, SI research remains in the preliminary exploration stage, and safety intelligence remains in a 游离 state in safety management (particularly safety informatization), lacking effective integration. Therefore, from an intelligence perspective, safety management requires a "break-the-boat"trans-

formation. Especially with the arrival of the big data era, safety management must integrate the "safety intelligence" concept. Only in this way can the goal of elevating safety information to safety intelligence be achieved amidst the vast ocean of complex safety information, thereby truly appreciating and releasing the value of safety information.

3. Evolution Trends of the Safety Intelligence Concept

As understanding deepens and social needs and environments evolve, many concepts (particularly in humanities and social sciences, such as "culture," "information," and "intelligence") undergo dynamic evolution. The safety intelligence concept is no exception. As safety needs, principal safety contradictions, safety situations, safety tasks, and safety problems and risks continue to evolve, the SI concept is constantly changing. Here, we briefly analyze the evolution trends of the SI concept to propose a concept better adapted to and aligned with current safety science research and practice needs.

From a historical perspective, combined with the evolution and development trends of safety science, the evolution trend of the SI concept can be generally summarized as "from fragmentation to unity," specifically manifested in three aspects: "from partial safety to overall safety," "from 'Security' to' Safety & Security Integration (SSI)," and "from emergency management to safety management."

3.1 Domain: From Partial Safety to Overall (Comprehensive) Safety

On April 15, 2014, President Xi Jinping [27] first proposed the great national security theory and concept of "Overall National Security View"at the first meeting of the Central National Security Commission, aiming to establish a national security system integrating political security, territorial security, military security, economic security, cultural security, social security, technological security, information security, ecological security, resource security, and nuclear security. From a system safety science perspective, if we combine the condition, state, and attribute of safety with any system (such as national systems, cultural systems, and ecological systems), we can derive a series of secondary safety concepts of "×× safety." Based on a safety science perspective and guided by the overall national security view, according to the different scales of protected object systems (according to Chinese safety scholar Professor Wu Chao' s [28] understanding, systems can be divided into three levels based on scale: macro-systems, meso-systems, and micro-systems), Chinese safety scholar Professor Luo Yun [29] roughly divides the safety science field into three primary domains:

(1) Macro-system safety (referred to as "large safety"), i.e., national security, mainly including political security, territorial security, military security, economic security, cultural security, technological security, information security, and ecological security as secondary safety domains.

(2) Meso-system safety (referred to as "medium safety"), i.e., public safety, mainly including food safety, disaster prevention and reduction, fire safety, traffic safety, nuclear safety, social security, counter-terrorism security, and campus safety as secondary safety domains.

(3) Micro-system safety (referred to as "small safety"), i.e., production safety (in China, habitually called "safe production"), mainly including occupational safety, occupational health, and industrial safety (mine safety, construction safety, chemical safety, metallurgical safety, and transportation safety, etc.) as secondary safety domains.

According to the different SI needs for safety management work in these three primary safety domains, SI can be divided into national security intelligence, public safety intelligence, and production safety intelligence, specifically explained as follows:

(1) National security intelligence. According to research, national security intelligence (including military security intelligence) is one of the earliest domains concerned and studied in intelligence science. Due to this historical background, even today, the vast majority of non-intelligence science fields or those without intelligence science backgrounds still limit their understanding of intelligence to national security and military (including military security) domains. After President Xi Jinping proposed the "Overall National Security View" in 2014, "national security intelligence" research has received widespread academic attention in China [30]. Of course, academia has proposed some secondary "×× safety intelligence" concepts belonging to the national security intelligence category. Searching the Web of Science database and China National Knowledge Infrastructure database reveals they mainly include: military security intelligence, information security intelligence (specifically involving cyber security intelligence or "cyber threat intelligence" and cyberspace security intelligence, etc.), and technological security intelligence.

(2) Public safety intelligence. The concept of public safety intelligence was proposed long ago. Tang Chao [9] believes that in China, since public security organs have long undertaken the vast majority of public safety tasks, public safety intelligence has always been regarded as synonymous with public security intelligence. From the above definition of public safety' s scope, this understanding is not entirely accurate and has certain limitations. Meanwhile, academia has proposed some secondary "×× safety intelligence" concepts belonging to the public safety intelligence category. Database searches reveal they mainly include: nuclear safety intelligence, food safety risk intelligence, disaster intelligence (specifically including earthquake disaster intelligence and natural disaster intelligence, etc.), fire intelligence, and counter-terrorism intelligence.

(3) Production safety intelligence. Literature review reveals that the production safety field has not yet formally proposed the specialized concept of

> "production safety intelligence." The main reason is perhaps that traditional production safety researchers generally have science and engineering backgrounds and lack humanities and social science (particularly intelligence science) backgrounds, which determines their understanding of safety informatization mainly focuses on the application of information technology in safety management, or remains only at the "safety information" level. Obviously, this understanding urgently needs to change and upgrade to the "safety intelligence" level, as detailed above.

Since President Xi Jinping proposed the "Overall National Security View"in 2014, Chinese safety scholars have gradually recognized that safety problems in various specific domains (such as public safety and production safety) intertwine and transform mutually. To achieve genuine safety development, we should establish "overall (comprehensive) safety" awareness and concepts. The author believes that so-called overall (comprehensive) safety means comprehensively building a safe country and society, with its core lying in the word "comprehensive," requiring that safety development in all domains must have no shortcomings. Safety work should focus on making up for the shortcomings of comprehensive safety, striving to ensure none are missing, none are lacking, and none are slow. This is also one of the important development trends of world safety science. Obviously, according to overall (comprehensive) safety requirements, current SI research still concentrates on serving partial safety management and urgently needs to develop toward serving overall (comprehensive) safety construction. Therefore, an important evolution trend of the SI concept should be from partial safety to overall (comprehensive) safety.

3.2 Connotation: From "Security" to "Safety & Security Integration (SSI)"

The Chinese term "安全" (safety) contains two layers of meaning, representing a combination of two English terms: "Safety" and "Security." Regarding the distinction between "Safety" and "Security," reference [31] provides a classic analysis: First, from the System & Environment (SE) dimension, "Security" relates to risks from the environment that potentially affect the system, while "Safety" deals with risks from the system that potentially affect the environment. Second, from the Malicious & Accidental (MA) dimension, "Security" typically addresses malicious risks, while "Safety" deals with purely accidental risks. For any system, its safety inevitably involves safety risks from both "Safety" and "Security" aspects, and sometimes the two transform mutually. Based on this understanding, for example, reference [31] proposes a system safety framework based on "System & Environment-Malicious & Accidental (SEMA)," shown in Figure 1 [Figure 1: see original paper] (Figure 1 has been modified and improved by the author). Figure 1 shows that all system safety issues are Safety & Security Integration (SSI) issues. From a system safety science perspective, so-called safety integration means that system safety risks include both "Safety" and "Security" aspects, and system safety promotion should focus on preventing

and controlling all safety risks (i.e., simultaneously addressing both aspects) [2]. For example, regarding urban system safety (referred to as "urban safety"), it involves the impacts and threats of natural disasters, social security cases, terrorist attacks, industrial accident disasters, underground pipeline safety issues, fires, traffic accidents, crowd crushes in public places, and injury incidents in primary and secondary schools and kindergartens on urban safety, covering both "Safety" and "Security" connotations and categories of safety risks, with risks from both aspects often intertwining and transforming mutually [32]. Wang Bing [32] believes urban safety issues are typical SSI problems.

Safety science has evolved through "empirical safety science → technical safety science → system safety science" [15] to today, with system safety science becoming the mainstream perspective for understanding, researching, and solving safety issues in both academic and practical circles [2, 15]. In short, system safety science means that the scope of safety science research and practice should be limited to the safety of a specific system (e.g., large-scale systems like national, social, urban, cultural, technological, and military systems, or small-scale systems like enterprise, community, and production systems). With the deepening of system safety science research, people have gradually recognized SSI issues. In view of this, the safety science community has begun to widely focus on Safety & Security Integration (SSI) research in recent years. For example: research on critical facilities and equipment safety, major engineering project safety, important industrial system safety, nuclear safety, and social public safety under the SSI perspective has received widespread attention; Delft University of Technology, one of the main birthplaces of safety science, has changed its "Safety Science Group" to "Safety & Security Science Group"; Central South University in China officially established the Safety & Security Theory Innovation and Promotion Center (STIPC) in 2017; the authoritative international journal in safety science, *Safety Science*, published a call for papers titled "Editor Security Research Selection" in 2018, specifically inviting research on safety integration; and so on.

From the above, it is clear that SI research has received widespread attention in the Security domain, but attention to safety intelligence in the Safety domain is scarce, basically remaining at the stage of safety information collection (the specific reasons have been briefly explained above). From a system safety science perspective, SI research aims to serve the promotion of overall system safety. Obviously, the current connotation of the SI concept mainly reflects the "Security" aspect, with seriously insufficient reflection of the "Safety" aspect, and even less ability to reflect the SSI connotation. Therefore, the connotation of the SI concept should transition and develop from "Security" to "Safety & Security Integration."

3.3 Link: From Emergency Management to Whole Safety Management Process

Due to the accidental, sudden, and urgent nature of emergency management work, intelligence is particularly important for emergency management. Consequently, emergency intelligence is considered the next important frontier in intelligence science research [25]. Indeed, current research achievements on emergency intelligence are numerous (e.g., [1, 13, 16, 25]). Regarding China' s emergency intelligence research, this mainly benefits from the high attention and support of the state and government. For example: China' s "Emergency Response Law of the People' s Republic of China," implemented in November 2007, explicitly emphasizes "intelligence cooperation" in emergency management [33]; recent national social science fund projects and youth projects have included multiple research topics on emergency intelligence (e.g., the 2018 National Social Science Fund annual and youth project list included research projects such as "Research on the Construction of Intelligence Engineering Service Mechanisms for Emergency Management") [34].

From a safety science perspective, safety management includes two aspects: "normal safety management (focusing on pre-event prevention)"and "abnormal safety management (i.e., emergency management, focusing on post-event response)." The "heavyweight" of safety management work should be "normal safety management." Both "normal safety management" and "emergency management" require intelligence support. However, regrettably, SI research oriented toward the whole safety management process (links) remains relatively rare (although research and practice in this area have been conducted in specific safety domains, such as the "intelligence-led policing" model in public safety and the "intelligence-led information security" approach in information security), with research mainly concentrated on SI for emergency management. Therefore, future SI concepts should shift from mainly facing emergency management links to facing the whole safety management process.

4. The Meaning of Safety Intelligence

Simply viewed, as a subordinate concept of intelligence, safety intelligence is safety-related intelligence. However, this understanding clearly lacks specificity, scientificity, and rigor, failing to indicate the utility and essence of safety intelligence and lacking safety science characteristics. Moreover, as discussed earlier, for the sake of unified understanding, comprehension, expression, and communication, to align with safety science development trends and SI concept evolution trends, and to avoid confusion among subordinate intelligence concepts, it is extremely necessary to scientifically define the SI concept from a safety science perspective.

The definition of intelligence has long been a focal point of debate in intelligence science, with no consensus reached to date [4, 20]. However, comprehensive analysis of intelligence definitions reveals two common understandings: First,

intelligence is "activated" and "processed" information; the essence of intelligence remains a type of information (in logical order, information comes first, then intelligence), and knowledge is the medium for transforming information into intelligence [21]. Second, if oriented toward management, intelligence research aims to serve management (mainly decision-making), and intelligence refers to all information (content) that affects management [20]. Based on these two common understandings and from a system safety science perspective (which has become the mainstream safety science paradigm today), this article proposes the following definition of safety intelligence: Safety intelligence refers to all safety-related information that influences system safety behavior.

To deeply understand the meaning of safety intelligence, it is necessary to briefly explain the core connotation of this definition: First, this definition directly reveals the essence of safety intelligence: the essence of safety intelligence is a type of safety information. Second, this definition reflects the value or utility of safety intelligence: influencing system safety behavior. Third, this definition highlights the gist of safety intelligence: organizational safety behavior is equivalent to system safety management (system safety management activities mainly include safety prediction activities, safety decision-making activities, and safety execution activities) [6], so safety intelligence aims to serve system safety management. Fourth, this definition can adapt to the evolution trend of the SI concept: as discussed above, the system safety science perspective is an excellent angle for defining safety intelligence, mainly because the SI definition based on system safety science can comprehensively reflect the connotations of "overall (comprehensive) safety," "safety integration," and "whole safety management process."

In summary, safety intelligence is the premise and foundation for conducting system safety management work, serving as the "eyes, ears, vanguard, and staff" of system safety management. Specifically, the fundamental cause of system safety management failure is safety intelligence deficiency. For system safety management, the value of safety intelligence is to solve the safety information deficiency problem in system safety management. Accordingly, based on the classification of system safety management activities (i.e., safety prediction activities, safety decision-making activities, and safety execution activities), we can summarize three specific main functions of safety intelligence:

(1) Safety intelligence can serve as a system' s safety prediction (early warning) support system. "Being able to discover, discover accurately, and discover early" is the prerequisite for mastering the initiative in system safety management. So-called "being able to discover, discover accurately, and discover early" refers to successful safety prediction (early warning), i.e., based on fully collecting, understanding, and mastering various safety information, analyzing this information to obtain effective safety intelligence, and then making advanced, correct, scientific, and precise safety predictions based on safety intelligence. In other words, safety intelligence helps discover system safety threats and safety promotion opportunities,

increases system safety managers' response time by increasing advanced safety early warning time, and thereby obtains advantages in system safety risk control to achieve prevention before problems occur.

(2) Safety intelligence can serve as a system' s safety decision-making support system. "Making good decisions, making quick decisions, and making economical decisions" are the basic requirements for formulating system safety management plans. So-called "making good decisions, making quick decisions, and making economical decisions" refers to successful safety decision-making, i.e., based on comprehensive assessment of various safety prediction intelligence, making scientific, reliable, effective, and economical safety decisions quickly based on optimal safety intelligence.

(3) Safety intelligence can serve as a system' s safety execution support system. "Preventing and controlling early, preventing and controlling effectively, and preventing and controlling successfully" are the ultimate goals of system safety management response. So-called "preventing and controlling early, preventing and controlling effectively, and preventing and controlling successfully"refers to successful safety execution, i.e., according to safety decision-making intelligence, timely, effectively, and thoroughly implementing safety decision plans (mainly various safety measures, including emergency management measures) to prevent and control various unsafe events, or to minimize the adverse consequences and impacts of unsafe events through effective emergency management measures.

Additionally, safety intelligence can serve as an important safety learning system for the system, not only helping system safety managers continuously access new safety ideas and advanced safety management methods but also enabling them to learn from accident lessons and experiences. In summary, safety intelligence work can provide specific clues and ideas for safety management work, as well as basis and reference. Safety intelligence work is an important way to obtain safety intelligence. Only when safety intelligence work is solid and effective can "advanced prevention," "keen awareness," and "precise policy implementation" be achieved in safety management.

Furthermore, realizing the value of safety intelligence depends on actively advocating and practicing the concept of "intelligence-led safety management." As an important concept in both safety science and intelligence science, safety intelligence represents the sublimation of safety information research and provides important guidance for innovating safety science (particularly safety informatics) theories and expanding the scope of intelligence science. Very regrettably, although safety science has developed rapidly in recent years, safety science researchers and practitioners have paid insufficient attention to the high-end link of the safety information chain— "safety intelligence," even losing this important concept. Fortunately, the intelligence science community has highly focused on SI research in recent years, making safety intelligence the next important frontier in intelligence science research. Obviously, the safety science community urgently needs to make due contributions and commitments to SI research.

Based on the above understanding, this article deeply discusses the origin, evolution trends, and meaning of the SI concept from a safety science perspective, aiming to timely compensate for current deficiencies in SI research and further open up new ideas for SI research.

As safety science researchers, the authors have increasingly felt the urgency and importance of SI research through long-term exploration in safety informatics. This article was written with great joy and eagerness, and we believe this discussion is also what other SI researchers anticipate. Of course, this article only serves as a modest introduction to SI research from a safety science perspective, hoping to 唤起 further attention and discussion on SI research from both intelligence science and safety science communities and promote dialogue and exchange among SI researchers from different fields. Meanwhile, due to space limitations, some viewpoints in this article may lack sufficient depth, or may inevitably be controversial, biased, or unreasonable. We sincerely request relevant researchers to offer criticism, corrections, and improvements, and we very much look forward to hearing from SI researchers in other disciplines.

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Author Contributions:
Wang Bing: Proposed the research direction and drafted the research framework, wrote and revised the paper.
Wu Chao: Proposed revision suggestions and revised the paper.

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