Forestry workers' perceptions on occupational safety: a comparative study of British Columbia and South Korea

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Abstract : Forestry remains one of the most hazardous industries, with significant risks of injuries and fatalities. This study compared the safety perceptions of forestry workers in British Columbia, Canada, and South Korea, two regions that practice sustainable forest management but differ in timber production methods and safety management experiences. The aim was to explore opportunities for region-specific safety management improvements in this critical sector. A total of 158 responses were analyzed, with 64 from British Columbia and 94 from South Korea. Participants rated their safety perceptions on a 5-point Likert scale, and an independent samples t-test assessed statistical differences. Both groups prioritized personal and coworker safety, valuing a safety-first culture over strict regulatory compliance. South Korean respondents preferred online training methods, while British Columbia respondents favored practical, on-site support. Both groups recognized the importance of mandatory certification for tree fallers, with British Columbia respondents additionally supporting regular refresher training. While British Columbia respondents prioritized expanding heavy machinery use to reduce accidents, South Korean respondents emphasized broader investments in safety measures. Both groups also favored incentive-based safety programs over penalties. Based on these insights, this study proposes region-specific strategies using the 4E framework. This study identified similarities and differences in forestry workers' perceptions based on regional forestry conditions and proposed effective, tailored safety management strategies for each region accordingly.

KEYWORDS: Safety, Perceptions, Occupational accident, Safety management, Forestry workers

1. Introduction

Forestry is essential for maintaining ecological balance, driving economic growth, and supporting social well-being through services such as carbon storage, biodiversity preservation, and timber production (FAO and UNEP 2020). Despite its significance, forestry is widely recognized as one of the most hazardous industries, particularly in timber production and management, where the risks of injuries and fatalities are high (ILO 2018). The physically demanding nature of forestry work, which often involves operating heavy machinery and handling large trees in remote, unpredictable environments, exacerbates these risks, leading to accidents such as falls, machinery-related incidents, and being struck by falling objects (FAO, ILO & United Nations 2023).

Forestry safety research has focused on risk assessment, safety interventions, worker perceptions, and incident analysis, providing a framework for understanding and mitigating risks. A number of studies have been conducted in North America (Frazier and Coleman 1983; Bell and Helmkamp 2003), Europe (Montorselli et al. 2010), New Zealand (Hinze et al. 2021), and other countries to investigate the causes of forestry accidents and propose preventive measures based on occupational accident statistics. Several studies have compared forestry fatality rates across countries based on timber harvest volumes or the number of workers (FAO 2018; Ackerknecht 2014; Albizu-Urionabarrenetxea et al. 2013). Research consistently highlights that motor-manual timber harvesting using chainsaws poses the highest accident risks (Myers and Fosbroke 1994). Through accident data analysis in South Korea, chainsaw operators were identified as particularly vulnerable to falling trees and chainsaw mishandling (Kim et al. 2013). Mechanization, which replaces chainsaw-based logging with machinery, has significantly reduced accidents, as seen in Sweden, the United States, and other regions. (Axelsson 1998; Bonauto et al. 2019; Bell 2002; Michael and Gorucu 2021). However, the mechanization of forestry operations has also introduced new challenges in workforce management and safety practices (FAO and UNEP 2020). Maintaining workplace health and safety requires legal compliance, effective policies, training programs, a strong safety culture, and proper equipment at worksites (FAO and UNECE 2020). Many studies have identified education and training as key factors in reducing accident rates in forestry. Research by Bell and Grushecky (2006) and Mujuru et al. (2009) emphasized the link between logger safety training and reduced accident rates. Meanwhile, other studies have focused on the effectiveness of specific training methods, such as video-based programs, in enhancing safety knowledge and behaviors (Helmkamp et al.

2004). Bell and Grushecky (2006) identified the use of feller buncher harvesting machines and an increased frequency of annual on-site inspections as effective measures in reducing injuries among logging workers, while suggesting that the impact of logging safety training programs is limited. A few studies have examined forest workers' opinions on safety issues, including their preferences and evaluations of programs, and have made comparisons across workers or regions, and suggested ways to improve forest safety management. Eagan (2005) found that loggers in northern New England mostly preferred less formal on-the-job training and argued that training should be tailored to the preferences and needs of the trainees. Conway et al. (2017) surveyed logging supervisors and crew members in the Southern United States and found that mechanization of timber harvesting has significantly reduced the hazards of the job, but accidents involving log trucking are on the rise, and human error related to machinery is an additional source of risk.

Worker involvement in safety management has also been shown to significantly improve effectiveness, as workers contribute direct knowledge of workplace hazards (ILO 2001; Saleem and Malik 2022). Worker perceptions and attitudes towards safety have become a crucial area of forestry safety research. Research focused on worker perceptions includes a study by Nieuwenhuis and Lyons (2002) in Ireland targeting harvesting contractors, and another by Bordas et al. (2001) in West Virginia, USA, which examined the perceptions of loggers regarding health and safety. Studies on forestry workers' satisfaction and preferences toward safety training have also been conducted in New England, USA (Egan 2005) and South Korea (Kim 2018). In British Columbia, research has been conducted to identify factors such as production pressures, fatigue, and lack of training and experience affecting worker safety (Olivotto et al. 2007), while another study highlighted ongoing concerns like traffic accidents and inadequate training (BCFSC 2022). Recently, studies have been conducted on the potential of utilizing IoT technology (König et al. 2024; Nam and Park 2020) and exoskeletons (Kim and Chung 2023) to prevent accidents among forestry workers. To reduce accidents in forestry, it is critical not only to comply with Occupational Health and Safety laws and regulations but also to implement robust safety management practices, such as comprehensive training programs, regular safety audits, and the use of personal protective equipment (FAO and UNECE, 2020). However, the variable conditions of forestry operations require ongoing adaptation to maintain safety standards (FAO, ILO & United Nations 2023). Research comparing forestry safety practices or perceptions across countries or among workers can help in developing more effective safety management strategies and programs.

This study investigates and compares the safety perceptions of forestry workers in two key regions: British Columbia, Canada (hereafter referred to BC), and South Korea (hereafter referred to as SK), where forestry plays a significant role in both economies and workforces. BC, a leading forestry region in Canada, has over 200 years of commercial logging history and approximately 55 million hectares of forest, which covers 57% of the province's total land area (Gilani and Innes 2020). In 2022, BC's forestry sector contributed $6.4 billion to the GDP and supported 56,000 jobs (Ministry of Forests 2024). In contrast, SK, a mountainous country with 6.3 million hectares of forest covering 63% of its land, initiated large-scale reforestation in the 1970s and 1980s, and timber harvesting from these reforested areas has steadily increased with the arrival of the felling age. Based on current forestry conditions, timber harvesting in BC is primarily mechanized (COS 2023). In contrast, the steep terrain that characterizes most of SK's forest regions result in a continued reliance on motor-manual methods using chainsaws (Kim et al. 2015).

Regarding the promotion of forestry safety, a significant turning point in BC was the establishment of the Forest Safety Task Force in 2003 to develop an action plan aimed at reducing deaths and serious injuries within the industry (British Columbia 2004). Following the creation of the BC Forest Safety Council in 2004 and its collaboration with WorkSafeBC, various safety management programs have been implemented to enhance forestry safety. In contrast, since 2010, SK has led forestry safety management through government agencies responsible for forestry and safety. The implementation of the Serious Accidents Punishment Act in 2022 has further heightened safety concerns within the industry in SK.

The objective of this study is to explore the safety perceptions of forestry workers in BC and SK—two regions pursuing sustainable forest management but differing in timber production methods and safety management practices. Based on these findings, the study proposes tailored strategies to improve safety management in each region.

2. Materials and methods

2.1 Survey participants and data collection

For the comparative study of forestry workers, participants included those engaged in forest management and harvesting operations in both BC and SK. In BC, participants were recruited voluntarily through announcements on the BC Forest Safety Council (BCFSC) website and notifications sent to member companies. Since most forestry companies in BC are members of the BCFSC, which facilitated broad

participation of forestry workers. In SK, recruitment involved the voluntary participation of forestry workers mainly from the National Forest Work Corps and the National Forestry Cooperative Federation work crews.

The survey was conducted using an online platform, Qualtrics, allowing participants to conveniently respond via mobile devices or PCs from remote locations. The questionnaire was provided in both English and Korean to ensure accessibility for all respondents. The survey was administered from February to May 2024. Out of 165 responses received, 158 valid responses were used for analysis after excluding incomplete and unreliable questionnaires, including 64 from BC and 94 from SK. Among BC respondents, 69% were affiliated with BC Forest Safety Council member companies, while 31% were from other organizations. Among SK respondents, 70% were with the National Forest Work Corps, and 30% were from other organizations.

2.2 Survey Design and Analysis Methods

The survey was designed to assess forestry workers' perceptions of various safety issues and was organized into four sections. The initial paper questionnaire draft was refined after thorough review and preliminary testing by the project team, peer experts, and target groups in BC and SK. The survey obtained ethical approval from the Behavioral Research Ethics Board of the Office at the University of British Columbia (No. H24-00247).

The questionnaire was divided into four sections and consists of a total of 38 items.

- **Section A:** Demographic information and work experience in the forestry sector (8 items).
- **Section B:** Perceptions of the current state and implementation of forestry safety (15 items).
- **Section C:** Perceptions on key topics for improving forestry safety management (7 Items)
- **Section D:** Evaluation of the effectiveness of proposed approaches and institutional programs to enhance forestry safety (8 items).

Participants responded using a 5-point Likert scale, measuring their level of agreement with safety-related statements (items) in Section C and D, and assessing the effectiveness of approaches presented in Section D. The scale ranged from 1 (Strongly Disagree/Very Low) to 5 (Strongly Agree/Very High). Average

scores were used to measure agreement and evaluation levels for each statement. To analyze the difference between the two groups, we conducted an independent samples t-test for perception and a chi-square test for group characteristics using SPSS software. This test compared the mean scores of the two groups for each statement to determine whether differences in perceptions were statistically significant at a significance level of 5% ($p < 0.05$). Levene's test was used to assess the equality of variances for each item. Depending on the outcome, either an independent samples t-test (for equal variances) or a Welch's t-test (for unequal variances) was applied to analyze differences between the groups for each item. The results are presented in tables and graphs, including the mean and standard deviation derived from the raw data for each question and comparison group (country). The t-test results are represented by the Mean Difference (MD), which measures the practical significance of the mean difference between the countries. p-values from the t-tests are also reported and interpreted in terms of statistical significance, indicating whether the sample size in the dataset is sufficient to detect small, medium, or large mean differences (MD) between the countries.

The hypotheses in this study were exploratory, and multiple statistical tests were conducted, leading to a multiple comparisons problem. This problem increases the Type I Error, or the probability of finding at least one false positive (also known as the statistical significance level), which rises with each additional test or p-value produced. The statistical hypotheses were organized into groups of questions: B1-B15 (15 tests), C1-C6 (6 tests), and D1-D8 (8 tests). To control for the family-wise Type I Error at 0.05, a Bonferroni correction was applied by dividing the original significance level of 0.05 by the number of tests in each group. For example, for questions B1-B15, the significance level was adjusted to $0.05/15 = 0.0033$. Similarly, for questions C1-C6, the adjusted significance level was $0.05/6 = 0.0083$, and for questions D1-D8, it was adjusted to $0.05/8 = 0.00625$.

In the discussion part, to propose tailored strategies for safety improvement in the two studied regions, the "4E safety framework"—commonly applied in the field of occupational safety, encompassing Education, Engineering, Enforcement, and Encouragement—was used, reflecting the findings of this study on workers' perceptions.

3. Results

3.1 Demographic and occupational background of the respondents

The demographic and occupational characteristics of respondents from BC and SK are presented in Table 1. Chi-square tests were used to assess differences in the distribution of demographic characteristics between the two groups. A significant age difference was found, with 90.6% of BC respondents aged 20 to 59, while 47.8% of SK respondents were 60 or older. Forestry work experience of respondents ranged from one to over 50 years, with both groups averaging approximately 18 years. More than half of BC respondents worked at companies with 50 or more employees, primarily in full-time positions. In contrast, over half of SK respondents worked for small businesses, with an average annual employment of 9 months. Additionally, about one-quarter of SK respondents were either temporary or contract workers. The primary forestry tasks also differed significantly. In BC, the most common task was Forest Management and Planning (23.2%), whereas in SK, 33.6% of respondents reported Silviculture as their main task. However, over 75% of respondents in both groups held job-related certifications, with the most frequent duration of annual training being two to three days, showing no significant differences between the groups.

(Table 1 here)

3.2 Perceptions of status of forestry safety

Section B consists of 15 items that examine workers' perceptions of forestry safety status and implementation (Table 2). The distribution of responses for each group to each item, as well as the results of the statistical analysis, including mean scores, standard deviations, and the significance of the mean difference, are presented in Table 3.

(Table 2 here)

(Table 3 here)

(Figure 1 here)

Both BC and SK respondents considered safety a crucial workplace factor, showing the highest mean scores among all B1-B15 items (mean ± standard deviation, BC: 4.64±0.78; SK: 4.83±0.54), with no significant difference between the groups (B1). Both groups also perceived that their companies prioritize worker safety over economic efficiency, with no significant difference observed (B2). In contrast, SK respondents expressed a significantly stronger belief than BC respondents that all forestry accidents can be prevented through thorough safety management (BC: 3.61±1.15; SK: 4.32±0.88; Mean Difference (MD) = 0.71, $p < 0.001$*) (B3). Both groups had similar perceptions regarding the status of safety management, scoring highly on the consistent use of personal protective equipment (PPE) (B4), knowledge of safety regulations (B6) and emergency measures (B10), compliance with safety regulations (B7), the ability to request early departure or sick leave (B8), and effective workplace safety management (B5), with no significant differences. However, SK respondents scored higher on the necessity to halt work and report unsafe conditions, indicating a stronger safety reporting culture (BC: 4.42±0.79; SK: 4.77±0.45; MD = 0.34, $p = 0.002$*) (B9).

Both groups perceived that forestry safety management has improved significantly compared to 10 years ago (B11). However, SK respondents showed a lower level of agreement than BC respondents regarding the statement that fatalities and injuries in the forestry sector are gradually decreasing (BC: 4.11±0.67; SK: 3.84±0.86; MD = 0.27, $p =0.029$) (B12). Both groups reported receiving helpful information and support for workplace safety management from professional organizations, with no significant differences (B13). Nevertheless, they showed relatively lower agreement regarding the statement that laws, regulations, and guidelines related to forestry safety are sufficient (B14). Moreover, BC respondents expressed lower agreement than SK respondents regarding the adequacy of risk assessment and management processes in the forestry workplace (BC: 3.64±0.88; SK: 4.03±0.74; MD = 0.39, $p =0.004$) (B15).

3.3 Perceptions of improvements in forestry safety management

Section C consists of 7 items (6 statements and one inquiry) that examine workers' perceptions on key topics for improving forestry safety management (Table 4). We presented approaches commonly recognized and adopted by countries with experience in forestry safety management, such as promoting a safety culture, strengthening safety regulations, expanding the use of heavy machinery, and enhancing training. The distribution of responses for each group to each item, as well as the results of the statistical

analysis, including mean scores, standard deviations, and the significance of the mean difference, are presented in Table 5.

(Table 4 here)

(Table 5 here)

(Figure 2 here)

Both BC and SK respondents emphasized that fostering a safety culture is more important than strengthening regulations for improving safety (BC: 4.47±0.69; SK: 4.38±0.79), with no significant difference between the groups (C1). Regarding the belief that increasing safety investment enhances economic feasibility, SK workers expressed significantly stronger agreement than BC workers (SK: 4.31±0.79; BC: 3.73±0.91), indicating a stronger perceived connection between safety investments and economic benefits (MD = 0.57, $p < 0.001$*) (C2).

BC workers expressed more support for expanding heavy machinery use to reduce forestry accidents, with a statistically significant difference compared to SK workers (MD = 0.56, $p < 0.001$*) (C3). Both groups showed the lowest agreement level increasing penalties for employers in serious-accident workplaces, with SK respondents' agreement significantly lower than BC's (MD = 0.53, $p = 0.004$*) (C4). Both groups agreed on the importance of expanding forestry education and training to improve safety, with no significant differences (C5). BC workers placed more emphasis on the need for periodic refresher training for certified tree fallers, showing a statistically significant difference compared to SK (MD = 0.54, $p < 0.001$*) (C6).

When asked about the potential for future reductions in serious injuries and fatalities (C7), more SK workers believed that a 50% or greater reduction is achievable, whereas a small portion of both groups thought the situation would remain unchanged (Figure 3). Overall, both BC and SK respondents expressed the most positive views on fostering a safety culture to improve forestry safety management and the most negative views on increasing employer penalties.

(Figure 3 here)

3.4 Evaluation of forestry safety improvement approaches

In Section D, BC and SK forestry workers evaluated the effectiveness of eight key approaches (measures or programs) aimed at improving forestry safety. Most measures are already implemented in BC, allowing BC respondents to evaluate from direct experience, while SK respondents assessed anticipated effectiveness for some measures not yet introduced. Responses were rated on a 5-point scale, from Very Low (1) to Very High (5). The analysis involved ranking each measure based on the average scores within each group and comparing the averages between the two groups. Tables 6 and 7 display the eight items and their corresponding results.

(Table 6 here)

(Table 7 here)

(Figure 4 here)

For the eight approaches aimed at improving forestry safety, both BC and SK workers commonly evaluated the mandatory system of certification for tree fallers (D4) and incentives for companies or organizations implementing improved safety management programs (D7) as the most and second-most effective measures, respectively. BC respondents ranked the certification program for companies with strong safety practices (D3) as the third most effective, while SK respondents chose diversifying safety training materials and providing online access (D1).

BC workers viewed the on-site support program for hand-falling safety (D2) more favorably than SK workers. Both groups considered mechanization (D5) to be moderately effective, with BC workers showing slightly more support. The system for reporting forestry safety incidents through a web portal or

app (D6) received similar ratings from both groups, indicating comparable views on its effectiveness. Regarding the approach of imposing greater penalties on companies with inadequate safety management (D8), both groups commonly rated it as having low effectiveness, placing it 7th. The evaluations of safety improvement approaches reveal shared views and key differences between BC and SK workers. Although no significant differences were found in group means for items D1 to D8 at a Bonferroni-adjusted significance level ($p < 0.00625$), the similar evaluations of various strategies suggest a shared understanding of key approaches for enhancing forestry safety. The results only suggest these shared similarities, as the hypotheses in this analysis were designed to test for differences rather than equivalence. Therefore, no direct evidence supports equivalence or similarities.

4. Discussion

This study explored the perceptions of forestry workers in BC and SK regarding various safety issues and conducted a statistical analysis of the differences in mean responses between the two groups. The findings provide meaningful insights by highlighting key areas for improvement and are anticipated to serve as a foundational resource for advancing safety management strategies tailored to the forestry sectors in each region. However, this study has many limitations as a descriptive comparative study. The overall strength of evidence is low, based on the exploratory nature of the hypotheses in this study. The major limitation and primary source of bias is that the comparison groups may have comparability issues based on their varying compositions in the respondents' affiliations, primary forestry tasks, employment relationships, company size and age distribution between BC and SK, which may have differences in their perceptions of various forest safety issues. Another source of bias is the subjectivity of the measures of the workers' perceptions. The biases stemming from this subjectivity could have been reduced if a suitable validated questionnaire with questions asked in unbiased way to measure the workers perceptions was available in the previous literature. Instead of validated questionnaire instruments, which are often tested for bias, objectivity, and accuracy, the questions in this survey were designed for this study specifically to address context-sensitive issues unique to the forestry workers. This in turn may have introduced subjectivity biases in the results of this study potentially reflecting the survey creators' biases rather than workers' true perceptions (Podsakoff et al., 2003). To the authors' current knowledge, the study includes a representative sample of the target population from each of the countries, and no obvious major subgroups are omitted from the sample. Although there may be biases due to over- or under-representation of certain subgroups,

as indicated in the demographic data summaries presented in Table 1.

The major limitation from the statistical analysis is related to the multiple comparison problem, which was mitigated by the Bonferroni correction discussed in the methods. Another limitation arises from the use of Likert scales, which are categorical ordinal variables. For this analysis, responses were approximated with numerical values to apply standard statistical methods for continuous outcomes. Because of this approximation of the ordinal categorical Likert scales with numerical values, the means and standard deviations are challenging to interpret due to the limited granularity of the Likert scale (1 to 5), making it difficult to relate derived values back to the original scale.

Nevertheless, the fact that participants in both groups have an average of approximately 18 years of experience in forestry and have observed and experienced the state of forestry safety management from the past to the present provides valuable insights for understanding the current status of forestry safety management and identifying future improvement strategies. The observation that respondents from both groups perceive a decrease in forestry fatalities over the past 20 years, consistent with statistical trends observed in this study (Figure 5), supports this view.

In addition to illustrating the trend of declining forestry fatalities in both regions, Figure 5 compares the average fatalities over the past 20 years, divided into five periods, while accounting for both the number of forestry workers and annual timber production in each region. For example, when comparing the average over the past five years (2017–2021), BC's fatality rate per million cubic meters of timber produced is significantly lower than SK's (0.12 vs. 3.31, approximately 1/27th) due to its high mechanization rate, which requires less labor. However, the fatality rate per 10,000 forestry workers is about three times higher in BC than in SK (4.78 vs. 1.60). When comparing these rates to industry averages, BC's rate is 7.8 times higher (4.78/0.61), and SK's is 1.5 times higher (1.60/1.08), highlighting the need for further safety measures in the forestry industry. As shown in Figure 3, approximately half of the surveyed forestry workers (44% in BC and 54% in SK) believe that serious injuries and fatalities could be reduced by over 50% through future safety improvements, underscoring the necessity of identifying improvement tasks in both regions.

(Figure 5 here)

To establish effective safety management measures, it is crucial to prioritize and select key areas based on workers' perceptions, especially those with field experience. Approaches that are rated as highly effective or revealed as relatively lacking in awareness should be considered as priority tasks. In the evaluation of eight approaches in Section D, BC respondents rated seven of the eight items higher, which can be interpreted as being influenced by central tendency bias due to limited knowledge of the program (Douven, 2017). Both groups rated the effectiveness of penalties relatively low and the expansion of incentives high, while SK respondents rated mechanization lower than BC respondents, possibly reflecting concerns over decline in forestry jobs (Cacot et al., 2015). These potential biases based on personal interests should be accounted for by policymakers.

Supporting the primary findings in existing literature, this study identifies key factors for safety improvements: fostering a safety culture, providing tailored education and training, reinforcing safety-related laws and regulations, shifting from motor-manual to harvesting machinery methods, and enhancing incentives to promote safety.

In this regard, safety management enhancement strategies for BC and SK are proposed based on identified safety issues of forestry workers in both regions, derived from research findings on safety perceptions. Using the 4E framework (Education, Engineering, Enforcement, and Encouragement), these region-specific strategies aim to reduce accidents and create safer working environments, considering workers' preferences while balancing effectiveness, feasibility, and implementation priorities. Additionally, Lundstrom et al. (2021) emphasize the importance of accounting for variations in safety perceptions among different groups of forestry workers when designing safety programs.

Therefore, based on the 4E framework, strategies to enhance forestry safety management in BC and SK are proposed as follows.

Education strategies are tailored to each region. In BC, the focus should be on expanding practical on-the-job training, including regular refresher courses for tree fallers and hands-on support for machine operators. There is also a need to enhance preventive education on musculoskeletal injuries and long-term health risks for heavy machinery operators, alongside training for vehicle drivers. In SK, where motor-manual timber harvesting still dominate, the priority should be strengthening on-site safety training for chainsaw operators adapted to diverse working conditions. Moreover, developing safety management training programs for small-scale business employers and supervisors is essential (Holiziki et al., 2013). Both

regions face the challenge of improving online training effectiveness, diversifying educational content, and providing training for young or inexperienced workers. These strategies align with previous research on forestry workers' preference for targeted safety programs (Eagan, 2005; Kim, 2018) and reflect the recommendations from the FAO and UNECE (2020), which emphasize focusing on vulnerable groups like young, inexperienced, temporary, and seasonal workers, while also enhancing education in response to mechanization, digitalization, and an aging workforce.

Engineering strategies focus on addressing the specific needs. In BC, where mechanized timber harvesting is prevalent, investments should be directed toward equipment that operates safely on hazardous terrain and includes hazard warning system. Further development and use of remote-controlled and semi-autonomous technology could also improve safety. In SK, despite the limitations of mechanized logging in mountainous areas (Montorselli et al., 2010), increasing mechanization to reduce chainsaw use remains a priority. However, the challenges posed by steep and mountainous terrain require consideration of tethered logging systems or the development of small to medium-sized logging machines suited to SK's conditions. Additionally, adopting IoT-based safety assist systems, like hazard-warning helmets, could reduce human error and help prevent serious accidents in both regions (Nam & Park, 2020; König et al., 2024).

Enforcement strategies encompass region-specific safety regulations and systems. BC has a well-established regulatory framework for forestry safety, supported by inspections, audits, and penalties to ensure compliance. To further strengthen this system, BC could enhance regulations including structured procedures for incident reporting and comprehensive risk assessment. Inspections could also be improved by incorporating standardized expert reviews, consultation-based methods, and real-time feedback. In contrast, SK lacks a systematic regulatory framework specifically tailored to forestry safety. Strengthening this framework by adopting models like BC's is a priority. Establishing a hand faller certification system, validated for its effectiveness in this study, should also be considered for priority adoption in SK due to its reliance on the high-risk of chainsaw operations.

Encouragement strategies involve creating supportive environments for safety improvements. BC offers various programs aimed at maintaining high safety standards in the forestry sector, including training, certification, and initiatives for continuous improvement. To enhance the impact of the SAFE Certification program, a pre-qualification safety initiative in BC forestry that sets minimum safety standards and recognizes companies committed to safety, introducing tiered recognition levels could incentivize the

ongoing elevation of safety standards. Modifying existing financial incentive programs through the insurer (WorkSafeBC) could also promote enhanced performance. In SK, developing incentive programs that foster a strong safety culture within companies is essential. This could involve a step-by-step introduction of financial support programs that align with workers' needs, such as increasing the standard proportion of safety management costs in contracted forestry work. Establishing a specialized institution to oversee forestry safety programs—similar to the BC Forest Safety Council—would further strengthen SK's safety efforts.

5. Conclusions

This study explored the similarities and differences in safety perceptions among forestry workers in BC and SK, revealing key findings that contribute to understanding how regional forestry environments influence safety perspectives.

The findings indicate that both BC and SK forestry workers prioritize workplace safety, favoring a safety-first culture over mere regulatory compliance. Despite this shared emphasis, significant differences emerged in training and machinery preferences: BC respondents supported increased use of heavy machinery and practical, on-site training, while SK respondents advocated for broader safety investments and preferred online training formats. Both groups also favored incentive-based safety programs over punitive measures, highlighting the need for tailored policies and programs suited to each region's unique forestry conditions and worker needs.

Informed by these findings, region-specific strategies were proposed using the 4E safety framework—Education, Engineering, Enforcement, and Encouragement. For BC, recommendations include enhancing practical, on-site training, improving machinery safety features, and refining inspection processes. In SK, priorities include advancing mechanization in logging, strengthening regulatory frameworks, and implementing comprehensive chainsaw training and certification. Both regions would benefit from adopting advanced safety technologies and expanding incentive programs to reinforce safety practices in forestry. Despite limitations related to respondent demographics and regional forestry characteristics, this study provides valuable insights into forestry workers' safety perceptions and serves as a foundation for developing tailored safety management strategies that reflect the unique conditions and needs of the BC and SK forestry sectors. By addressing these findings, policymakers and industry stakeholders can

enhance safety outcomes and create safer working environments for forestry workers in both regions.

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Table 1. Demographic and occupational details of survey respondents

Characteristic	British Columbia (n=64)	South Korea (n=94)	P-value (χ^2 test)
Age	n(%)	n(%)	
20~29	13(20.3%)	1(1.1%)	*p<0.001***
30~39	14(21.9%)	5(5.3%)	
40~49	15(23.4%)	10(10.6%)	
50~59	16(25.0%)	33(35.1%)	
60~69	6(9.4%)	43(45.7%)	
70 and above	0(0%)	2(2.1%)	
Work experience in Forestry			
1~4 years	11(17.2%)	12(12.8%)	*p=0.486*
5~9 years	7(10.9%)	12(12.8%)	
10~19 years	17(26.6%)	28(29.8%)	
20~29 years	14(21.9%)	23(24.5%)	
30~39 years	11(17.2%)	16(17.0%)	
40~49 years	4(6.3%)	1(1.1%)	
50~ years	0(0%)	2(2.1%)	
Annual work Period			
1~3 months	2(3.1%)	3(3.2%)	*p<0.001***
4~6 months	5(7.8%)	20(21.3%)	
7~9 months	1(1.6%)	20(21.3%)	
10~11 months	3(4.7%)	29(30.9%)	
12 months	53(82.8%)	22(23.4%)	
Employer or Employee			
Employer (including Self-employed)	6(9.4%)	33(35.1%)	*p<0.001***
Employee (Permanent worker)	54(84.4%)	37(39.4%)	
Employee (Temporary/Contract worker)	4(6.3%)	24(25.5%)	
Number of Employees			
1~4	2(3.1%)	3(3.2%)	*p<0.001***
5~9	6(9.4%)	53(56.4%)	
10~29	11(17.2%)	37(39.4%)	
30~49	6(9.4%)	1(1.1%)	
50~99	19(29.7%)	0(0%)	
100~299	6(9.4%)	0(0%)	
300 or more	11(17.2%)	0(0%)	
No response (Don't know/ Other)	3(4.7%)	0(0%)	
Primary Task in Forestry work			
General Management	15(15.2%)	29(13.4%)	N/A
Motor-manual work (chainsaw etc.)	2(2.0%)	57(26.3%)	
Machine operator	6(6.1%)	12(5.5%)	
Silvicultural work (planting etc.)	2(2.0%)	73(33.6%)	
Loading and Transportation	12(12.1%)	15(6.9%)	
Forest Management and Planning	23(23.2%)	3(1.4%)	
Supervision	16(16.2%)	23(10.6%)	
Other	23(23.2%)	5(2.3%)	
Sub-total (multi-response)	99(100%)	217(100%)	
Hold Certification related to Task			
Yes	48(75.0%)	81(86.2%)	*p=0.153*
No	13(20.3%)	9(9.6%)	
Currently in the process of obtaining	3(4.7%)	4(4.3%)	
Duration of Training per year			
None	0(0.0%)	1(1.1%)	*p=0.117*
Less than 6 hours	1(1.6%)	8(8.5%)	
1 day (6~8hours)	8(12.5%)	10(10.6%)	
2~3 days	25(39.1%)	22(23.4%)	
4~5 days	9(14.1%)	17(18.1%)	
1~2 weeks	16(25.0%)	18(19.1%)	
3~4 weeks	3(4.7%)	10(10.6%)	
More than a month	2(3.1%)	8(8.5%)	

Note: ***p < 0.001.

569 Table 2. Survey questions on perceptions of current forestry safety conditions.

Section B. Please indicate your level of agreement to the following statements about your perception regarding forestry safety.
B1. I consider the safety of myself and my colleagues as the most important factor in the forestry workplace.
B2. My company (organization/workplace) prioritizes worker safety over economic efficiency.
B3. I believe that all forestry accidents can be prevented through thorough safety management.
B4. I always wear appropriate personal protective equipment while working.
B5. My company (organization/workplace) generally manages workplace safety well.
B6. I am knowledgeable about the safety regulations related to my work/job.
B7. I am actively complying with the safety regulations related to my work/job.
B8. I can request early departure or sick leave on a working day if I suddenly experience health issues.
B9. If a safety issue arises during my work, I must halt work and promptly report the unsafe conditions to my supervisor or employer.
B10. I am knowledgeable about and capable of handling emergency measures, including first-aid, in the event of a workplace safety incident.
B11. I believe that safety management in forestry workplaces has improved compared to ten years ago.
B12. The number of fatalities or injuries in forestry including logging operations is gradually decreasing compared to the past.
B13. I receive helpful information and support for workplace safety management from relevant professional organizations in the field of forestry.
B14. I believe that there are sufficient laws, regulations, standards and guidelines (operational manuals) related to forestry safety.
B15. I believe that the process of risk assessment and risk management in the forestry workplace are adequate.

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583 Table 3. Response counts and agreement levels on forestry safety status statements.

	British Columbia (n=64)							South Korea (n=94)							Comparison of Means	
	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Mean (A)	Std. dev.	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Mean (B)	Std. dev.	P-value (t-test)	Difference (A-B)
B1	2	0	0	15	47	4.64	0.78	1	0	1	10	82	4.83	0.54	0.097	-0.19
B2	1	0	4	28	31	4.38	0.75	0	0	7	25	62	4.59	0.63	0.058	-0.21
B3	2	12	11	23	16	3.61	1.15	1	4	8	32	49	4.32	0.88	<0.001*	-0.71
B4	1	4	0	21	38	4.42	0.91	0	1	4	23	66	4.64	0.62	0.099	-0.22
B5	1	2	2	29	30	4.33	0.82	0	0	3	37	54	4.54	0.56	0.052	-0.21
B6	1	0	0	30	33	4.47	0.67	1	0	4	39	50	4.46	0.68	0.918	0.01
B7	1	0	3	27	33	4.42	0.73	0	1	5	37	51	4.47	0.65	0.677	-0.05
B8	1	1	2	21	39	4.50	0.78	0	1	4	32	57	4.54	0.63	0.706	-0.04
B9	1	1	3	24	35	4.42	0.79	0	0	1	20	73	4.77	0.45	0.002*	-0.34
B10	1	1	2	31	29	4.34	0.76	0	0	5	35	54	4.52	0.60	0.104	-0.18
B11	1	1	4	25	33	4.38	0.81	1	1	7	45	40	4.30	0.75	0.538	0.08
B12	0	1	8	38	17	4.11	0.67	1	3	28	40	22	3.84	0.86	0.029	0.27
B13	1	0	5	38	20	4.19	0.71	1	0	15	49	29	4.12	0.75	0.553	0.07
B14	1	1	7	38	17	4.08	0.76	3	1	22	42	26	3.93	0.92	0.275	0.15
B15	1	7	13	36	7	3.64	0.88	0	1	21	46	26	4.03	0.74	0.004	-0.39

584 Note: *p < 0.05/15 = 0.0033, Bonferroni corrected significance level for 15 tests.
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596 Table 4. Survey questions regarding perceptions on key topics for improving forestry safety management

Section C. Please indicate your level of agreement to the following statements about improving forestry safety management.
C1. I believe that fostering a culture that prioritizes and practices safety and health is more crucial for enhancing safety than strengthening regulatory measures.
C2. Increasing investment (expenditure) in safety eventually becomes the key to enhancing the economic feasibility and success of the business.
C3. Expanding the introduction of heavy equipment such as harvesters or forwarders to replace manual labor in forestry harvesting operations helps reduce industrial accidents.
C4. Increasing penalties for employers in the event of serious accidents due to insufficient safety measures in the workplace can help reduce incidents.
C5. Increasing forestry education and training (content and duration) is crucial for improving safety in forestry workplaces.
C6. Even certified tree fallers need periodic (at least every 2-3 years) refresher training to enhance safety.
C7. If forestry safety practices are improved, how much do you think it is possible to reduce fatalities and serious injuries compared to the present level?

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600 Table 5. Response counts and agreement levels on key topics for improving forestry safety management.

	British Columbia (n=64)							South Korea (n=94)							Comparison of Means	
	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Mean (A)	Std. dev.	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Mean (B)	Std. dev.	P-value (t-test)	Difference (A-B)
C1	1	0	1	28	34	4.47	0.69	1	0	7	40	46	4.38	0.72	0.456	0.09
C2	0	6	19	25	14	3.73	0.91	1	1	10	38	44	4.31	0.79	<0.001*	-0.57
C3	1	5	10	32	16	3.89	0.93	5	14	36	23	16	3.33	1.09	<0.001*	0.56
C4	3	5	15	33	8	3.59	0.97	15	14	29	22	14	3.06	1.28	0.004*	0.53
C5	0	2	11	36	15	4.00	0.74	3	1	27	40	23	3.84	0.92	0.229	0.16
C6	0	3	10	29	22	4.09	0.83	4	10	31	28	21	3.55	1.08	<0.001*	0.54

601 Note: *p < 0.05/6 = 0.0083, Bonferroni corrected significance level for 6 tests.

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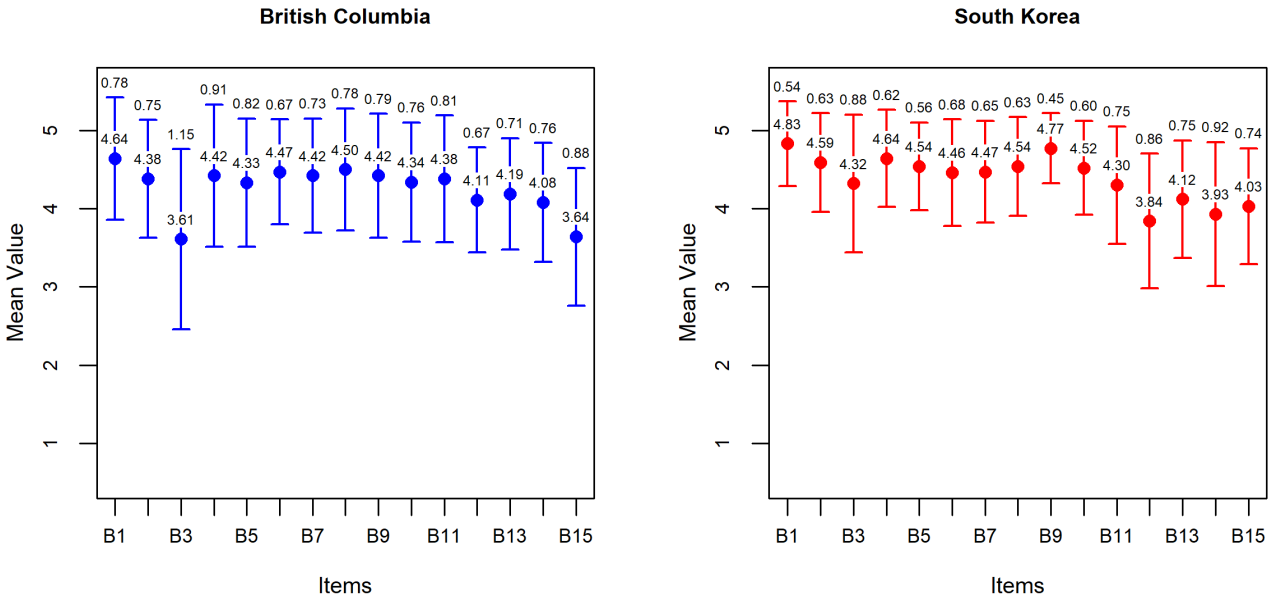

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607 Figure 1. The plots summarize responses from all participants for questions B1-B15 across the comparison
608 groups (countries, BC and SK). Points represent means for each question B1-B15, and vertical error bars
609 indicate the respective standard deviations, as shown in Table 3.

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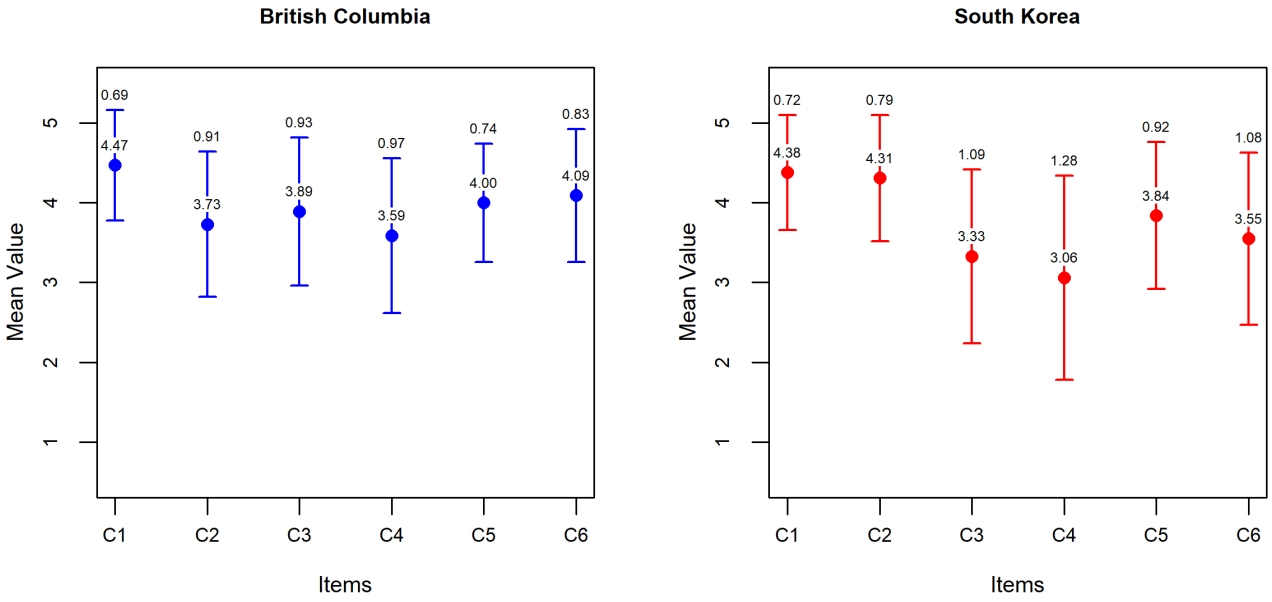

Figure 2. The plots summarize responses from all participants for questions C1-C6 across the comparison groups (countries, BC and SK). Points represent means for each question C1-C6, and vertical error bars indicate the respective standard deviations, as shown in Table 5.

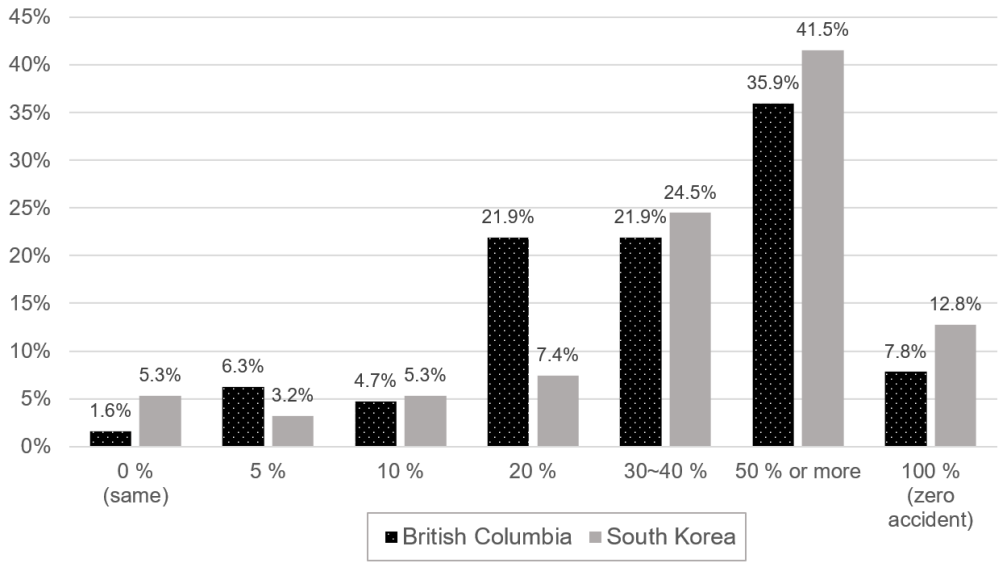

Figure 3. Distribution of responses from both groups on the potential for future reductions in serious injuries and fatalities (percentages sum to 100% per group).

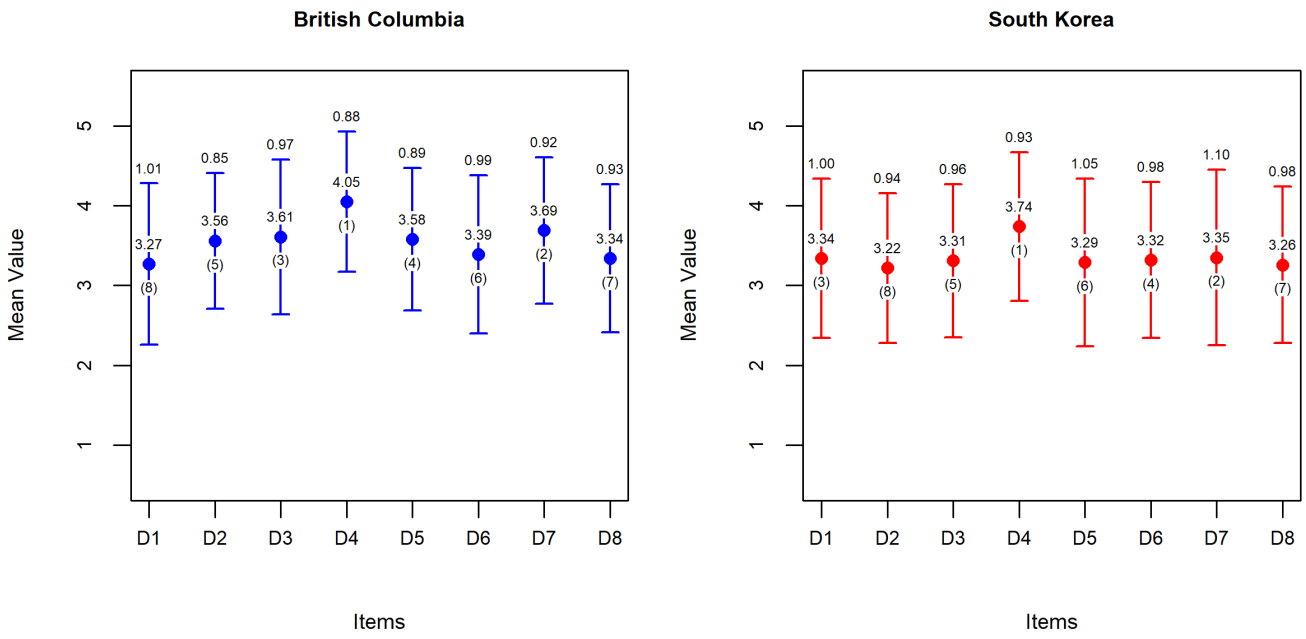

Figure 4. The plots summarize responses from all participants for questions D1-D8 across the comparison groups (countries, BC and SK). Points represent means for each of the questions D1-D8, and vertical error bars indicate the respective standard deviations, as shown in Table 7. The numbers in brackets indicate the ranking of the magnitude of the means within each comparison group (country, BC and SK).

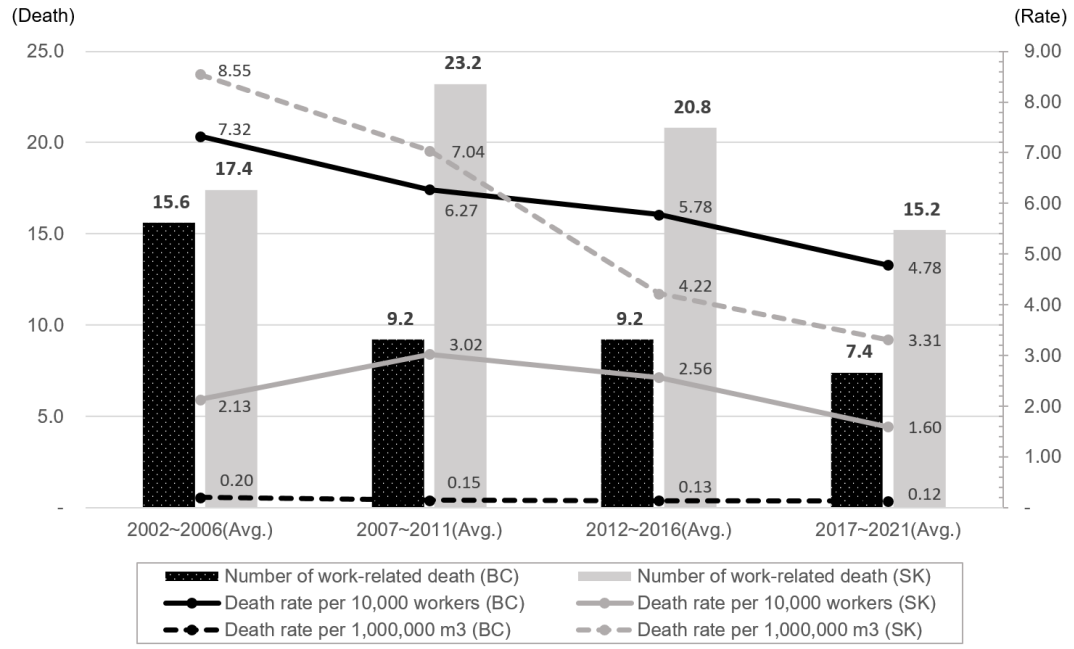

Figure 5. Comparison of periodic annual average forestry fatalities and fatality rates per 10,000 workers and per 1 million m³ of wood production in British Columbia (BC) and South Korea (SK) over 20 years (2002–2021) (Data sources: WorkSafeBC, Korea Occupational Safety and Health Agency, Ministry of Forests BC, Korea Forest Service).