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Comparative Analysis of Shoe Size Standards Based on Foot Measurement Methods: Evidence from Indonesian and International Standards

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Abstract: The footwear industry is one of the strategic manufacturing sectors that contributes significantly to economic growth through employment, value creation, and export activities. Accurate shoe sizing is essential to ensure consumer comfort, product quality, and international market competitiveness. This study aimed to compare the Indonesian National Standard (SNI) shoe sizing system with major international sizing systems based on foot measurement methods, evaluate the regulatory implications of SNI implementation, and propose a harmonized sizing framework for the footwear industry. A descriptive comparative approach was employed through literature review, document analysis of national and international standards, comparative evaluation of shoe sizing systems, observation of foot measurement methods, and regulatory analysis. The results indicate that the SNI sizing system has a high level of compatibility with the Mondopoint system because both are based on actual foot length measured in millimeters. In contrast, the European Union, United Kingdom, and United States sizing systems use different numbering principles that require conversion. A Mondopoint-based dual-labeling approach is proposed to improve sizing accuracy, reduce product returns, facilitate international trade, and strengthen the competitiveness of Indonesian footwear products. These findings provide practical support for future footwear standardization policies and industrial implementation.

Keywords: shoe sizing, Indonesian National Standard, Mondopoint, standardization, footwear industry

INTRODUCTION

The footwear industry is one of the most important manufacturing sectors worldwide, contributing substantially to economic growth through employment generation, industrial value creation, and international trade. Increasing globalization and the rapid expansion of e-commerce have intensified competition among footwear manufacturers, requiring continuous

improvements in product quality, manufacturing efficiency, and consumer satisfaction. Besides material quality and production technology, an accurate shoe sizing system has become an essential component of product quality because it directly influences footwear fit, comfort, functionality, and purchasing decisions. From the perspective of industrial standardization, consistent sizing systems also facilitate quality assurance, conformity assessment, and market interoperability, thereby supporting both domestic distribution and international trade (Blind, 2004; International Organization for Standardization & International Electrotechnical Commission, 2004; Swann, 2010).

Accurate shoe sizing fundamentally depends on reliable foot anthropometric measurements. Human feet exhibit considerable variations in length, width, arch height, and overall morphology due to differences in sex, age, ethnicity, and body composition, making standardized measurement methods essential for footwear design and manufacturing. Previous anthropometric studies demonstrated that foot morphology differs significantly across population groups and that inappropriate shoe sizing may reduce comfort, increase plantar pressure, contribute to musculoskeletal disorders, and elevate product return rates, particularly in online retail where consumers cannot physically evaluate footwear before purchase (Hawes et al., 1994; Krauss et al., 2008; Mauch et al., 2008; Menz & Morris, 2005; Wunderlich & Cavanagh, 2001). Consequently, foot anthropometry has become a fundamental scientific basis for footwear engineering and ergonomic product development Goonetilleke (2012; Nigg, 1986).

To improve measurement consistency, several shoe sizing systems have been developed internationally, including the European Union (EU), United Kingdom (UK), United States (US), China (CN), and Mondopoint systems. Unlike conventional numbering systems that are derived from historical measurement units such as the Paris Point and Barleycorn, the Mondopoint system determines shoe size directly from actual foot length measured in millimeters, providing a more objective and scientifically consistent anthropometric reference. Advances in digital measurement technologies, including three-dimensional foot scanning, computer vision, and mobile-based foot measurement systems, have further improved the accuracy and reproducibility of foot measurements for footwear customization and industrial production (Boppana & Anderson, 2021; Kabir et al., 2021; Luximon et al., 2005; Sikaroudi et al., 2017; Xiong et al., 2010). Recognizing these advantages, the International Organization for Standardization recommends the Mondopoint system as the international reference for footwear sizing harmonization through ISO 9407:2019, while ISO 19407:2023 provides standardized conversion among different international shoe sizing systems and ISO 19410-1:2022 establishes standardized in-shoe measurement procedures to improve sizing consistency across footwear products.

In Indonesia, footwear sizing is regulated through the Indonesian National Standard (SNI), which adopts the Mondopoint concept as the primary basis for determining shoe size using actual foot length. This approach provides a more objective sizing system than conventional numerical systems because it is directly derived from anthropometric measurements rather than historical numbering conventions. Nevertheless, many Indonesian footwear manufacturers continue to apply European, United Kingdom, or United States sizing systems, particularly for export-oriented production and international branding. Consequently, different sizing systems often coexist within the same product category, creating inconsistencies in size labeling, increasing the complexity of international size conversion, and potentially reducing consumer confidence in cross-border transactions. From a regulatory perspective, the implementation of SNI is supported by the Indonesian Standardization and Conformity Assessment Act (Pemerintah Republik Indonesia, 2014) and Government Regulation No. 34 of 2018 (Pemerintah Republik Indonesia, 2018), which establish the legal framework for the development, implementation, and conformity assessment of national standards. The harmonization of national and international footwear standards is therefore

essential not only for improving industrial competitiveness but also for strengthening consumer protection and facilitating international trade.

Previous studies have investigated footwear sizing from various perspectives, including anthropometric measurement, footwear ergonomics, digital foot measurement technologies, and customized footwear design. Chang & Lee (2019) demonstrated that body posture and loading conditions significantly influence measured foot dimensions, indicating that standing and sitting positions may produce different sizing outcomes. Anggoro et al. (2021) applied reverse engineering techniques to develop customized orthotic insoles based on accurate foot anthropometry, emphasizing the importance of dimensional precision in footwear manufacturing. Other studies have focused on improving measurement accuracy through digital technologies, including three-dimensional foot scanning, computer vision, and mobile-based measurement applications, which offer higher precision and repeatability than conventional manual methods (Boppana & Anderson, 2021; Kabir et al., 2021; Luximon et al., 2005; Sikaroudi et al., 2017; Xiong et al., 2010). In Indonesia, several studies have also explored foot anthropometry and digital measurement systems for footwear applications, including anthropometric database development, three-dimensional foot scanning, and image-based shoe size determination (Pratikno & Kusumawati, 2022; Waluyono, 2020; Wibowo et al., 2021). Collectively, these studies demonstrate substantial progress in anthropometric measurement techniques; however, their primary emphasis remains on technical measurement accuracy rather than standard harmonization or regulatory implementation.

Despite these developments, several important research gaps remain. First, existing studies predominantly investigate anthropometric measurement methods or footwear ergonomics without comparatively evaluating different international shoe sizing systems based on standardized foot measurements. Second, previous research rarely examines the relationship between technical sizing systems and national standardization policies, despite the important role of standards in supporting industrial quality assurance and international market access. Third, studies integrating foot anthropometry, international shoe sizing systems, regulatory implementation, and industrial competitiveness into a single analytical framework remain limited, particularly in the Indonesian context. Consequently, there is still insufficient evidence regarding how harmonized shoe sizing standards can simultaneously improve measurement consistency, facilitate international size conversion, strengthen regulatory implementation, and enhance the competitiveness of the Indonesian footwear industry.

Addressing these research gaps requires an integrated perspective that combines technical measurement principles, international standardization, and regulatory implementation. Standardization should not merely be regarded as a technical instrument for product specification but also as a strategic mechanism for improving industrial efficiency, facilitating international trade, reducing technical barriers, and enhancing consumer confidence. From an economic perspective, harmonized standards promote market interoperability, improve production consistency, and support innovation by providing common technical references across industries (Blind, 2004; Swann, 2010). In the footwear sector, integrating anthropometric measurements with internationally harmonized sizing standards may reduce sizing inconsistencies, minimize product returns, and improve communication between manufacturers, retailers, and consumers across different markets.

The novelty of this study lies in the development of an integrated analytical framework that simultaneously evaluates three interrelated dimensions of footwear sizing. First, this study comparatively analyzes the Indonesian National Standard (SNI) and major international shoe sizing systems, including Mondopoint, European Union (EU), United Kingdom (UK), United States (US), and China (CN), using standardized foot measurement principles. Second, it examines the influence of different foot measurement methods on shoe size determination by considering both conventional anthropometric techniques and recent developments in digital foot measurement technologies. Third, the study extends previous research by incorporating

regulatory analysis into the technical evaluation of shoe sizing systems, thereby linking measurement accuracy with national standardization policies and industrial implementation. This integrated perspective has received limited attention in previous footwear studies, which have generally focused on either anthropometric measurement, footwear ergonomics, or digital technologies as separate research domains.

The findings of this study are expected to contribute both theoretically and practically. From a theoretical perspective, the study expands the literature on footwear standardization by integrating anthropometric measurement, footwear ergonomics, international standardization, and regulatory policy into a unified analytical framework. From a practical perspective, the proposed harmonization model may assist policymakers, standardization agencies, and footwear manufacturers in improving national shoe sizing systems through Mondopoint-based dual labeling while maintaining compatibility with international markets. Such harmonization is expected to improve measurement consistency, reduce product return rates, strengthen consumer protection, and enhance the global competitiveness of Indonesian footwear products.

Therefore, this study aims to (1) compare the Indonesian National Standard (SNI) shoe sizing system with major international shoe sizing systems based on foot measurement methods; (2) evaluate the influence of different foot measurement methods on shoe size determination; (3) examine the regulatory implications of SNI implementation in the Indonesian footwear industry; and (4) propose a harmonized shoe sizing framework that supports industrial standardization, consumer protection, and international trade.

METHOD

Study Design

This study employed a descriptive comparative research design integrating quantitative comparative analysis and qualitative document analysis to evaluate shoe sizing systems and the implementation of the Indonesian National Standard (SNI) in the footwear industry. The quantitative analysis compared the characteristics of the SNI, Mondopoint, European Union (EU), United Kingdom (UK), United States (US), and China (CN) shoe sizing systems based on foot measurement principles, while the qualitative analysis examined national standardization policies and regulatory frameworks related to SNI implementation. This integrated approach enabled a comprehensive assessment of both the technical and regulatory dimensions of footwear standardization (Blind, 2004; Creswell & Creswell, 2018; Swann, 2010).

The research comprised four sequential stages: (1) identification and review of national and international shoe sizing standards, (2) comparison of foot measurement methods and their influence on shoe size determination, (3) analysis of regulations governing SNI implementation, and (4) development of a harmonized shoe sizing framework. These stages provided a systematic understanding of the relationship between foot anthropometry, shoe sizing systems, and standardization policies in the Indonesian footwear industry (Goonetilleke, 2012; International Organization for Standardization, 2019, 2023).

Study Area and Research Objects

The study was conducted in the Indonesian footwear industry, involving small-, medium-, and large-scale manufacturers that apply national or international shoe sizing systems in their production and marketing activities. Field observations were complemented by document analysis of standards issued by the Indonesian National Standardization Agency (BSN), the International Organization for Standardization (ISO), and Indonesian regulations related to product standardization and conformity assessment. This combination enabled a comprehensive evaluation of both the technical characteristics of shoe sizing systems and the regulatory framework governing their implementation (Blind, 2004; Pemerintah Republik Indonesia, 2014, 2018; Swann, 2010).

The research focused on the Indonesian National Standard (SNI), which adopts the Mondopoint concept, together with the ISO Mondopoint, European Union (EU), United Kingdom (UK), United States (US), and China (CN) shoe sizing systems. These systems were selected because they represent the most widely used standards in domestic and international markets and differ in their measurement principles and size conversion methods. In addition, the regulatory framework for SNI implementation was analyzed to evaluate its compatibility with international shoe sizing standards and identify opportunities for harmonization to strengthen industrial competitiveness and consumer protection.

Research Variables

The study analyzed several variables associated with shoe sizing systems, foot anthropometry, and standardization performance. These variables were selected to evaluate the compatibility of national and international shoe sizing systems based on foot measurement methods and to assess the implementation of standardization within the footwear industry. The variables, indicators, and units of measurement are presented in Table 1. The selection of these variables was based on internationally recognized footwear sizing standards and anthropometric measurement principles commonly applied in footwear research and industrial practice.

Table 1. Research Variables

Variable	Indicator	Unit
Foot length	Heel-to-toe length	mm
Foot width	Ball width	mm
SNI shoe size	Size number	Size
EU shoe size	Paris Point	Size
UK shoe size	Barleycorn	Size
US shoe size	Barleycorn	Size
Mondopoint	Foot length	mm
Size compatibility	Conversion error	mm
Harmonization level	Compatibility percentage	%
Regulatory compliance	SNI implementation	Yes/No

Source: Developed by the authors (2026).

Data Sources

This study employed both primary and secondary data to evaluate shoe sizing systems and the implementation of national standardization in the Indonesian footwear industry. The use of multiple data sources enabled methodological triangulation and improved the reliability of the findings (Bowen, 2009; Creswell & Creswell, 2018). Primary data were collected through direct foot measurements using the Mondopoint and Brannock Device methods, field observations of shoe sizing practices, and semi-structured interviews with footwear practitioners, academics, and standardization experts. These data were used to compare the accuracy of different foot measurement methods and examine their practical implementation in the footwear industry (Chang & Lee, 2019; Goonetilleke, 2012). Secondary data included national and international standards, regulatory documents, and relevant scientific literature, including SNI 7037:2009, ISO 9407:2019, ISO 19407:2023, ISO 19410-1:2022, Law No. 20 of 2014, Government Regulation No. 34 of 2018, peer-reviewed journal articles, BSN reports, and official publications from the Ministry of Industry. These sources provided the technical and regulatory basis for comparing shoe sizing systems and evaluating the harmonization of national and international standards.

Data Collection

Data were collected through four complementary techniques: literature review, field observation, direct foot measurement, and semi-structured interviews. The literature review

provided the theoretical foundation by examining national and international shoe sizing systems, foot anthropometry, measurement methods, footwear ergonomics, digital foot scanning technologies, and footwear standardization policies (Goonetilleke, 2012; Xiong et al., 2010).

Field observations were conducted in footwear manufacturing facilities and the Footwear Technology Laboratory of Politeknik ATK Yogyakarta to examine shoe sizing procedures and compare industrial practices with internationally recognized standards. Direct anthropometric measurements were performed using five methods: Mondopoint, Brannock Device (standing), Brannock Device (sitting), tape measurement, and the SNI rounded 5-mm method. Each participant was measured three times with each method, and the mean value was used for statistical analysis to improve measurement reliability (Chang & Lee, 2019; International Organization for Standardization, 2019). Semi-structured interviews were conducted with footwear manufacturers, academics, standardization experts, and representatives of product certification bodies to obtain insights into the implementation of shoe sizing standards, industrial challenges, and opportunities for harmonizing SNI with international sizing systems. The integration of these data collection techniques ensured methodological triangulation and strengthened the credibility of the research findings.

Research Instruments

The research employed several instruments to support data collection and analysis. A Brannock Device was used to measure foot length and width according to internationally recognized anthropometric procedures, while a digital ruler was used to verify linear measurements. Where available, a three-dimensional foot scanner was utilized to obtain digital foot geometry for comparison with conventional measurement methods. Statistical analyses were performed using IBM SPSS Statistics version 29 and Minitab version 22, whereas Microsoft Excel was used for data organization and preliminary calculations. AutoCAD and Fusion 360 software were employed to visualize foot dimensions and compare shoe sizing systems. The functions of each research instrument are summarized in Table 2.

Table 2. Research Instruments

Instrument	Function
Brannock Device	Foot length and width measurement
Digital ruler	Verification of foot length measurements
3D Foot Scanner (optional)	Digital acquisition of foot geometry
Microsoft Excel	Data organization and tabulation
IBM SPSS Statistics 29	Statistical analysis
Minitab 22	Comparative statistical analysis
AutoCAD / Fusion 360	Visualization of foot dimensions

Source: Developed by the authors (2026).

Research Procedure

The research procedure consisted of four sequential stages, as illustrated in Figure 1. The first stage involved reviewing national and international shoe sizing standards through literature review and document analysis. The second stage consisted of collecting anthropometric data using multiple foot measurement methods and comparing shoe sizes derived from different sizing systems. The third stage involved evaluating the implementation of Indonesian footwear standardization policies through regulatory analysis and qualitative information obtained from interviews and field observations. Finally, the technical and regulatory findings were integrated to develop a harmonized shoe sizing framework capable of improving compatibility between the Indonesian National Standard and international shoe sizing systems. This systematic procedure ensured that the analysis addressed both the technical and regulatory dimensions of footwear standardization.

Data Analysis

Data were analyzed using descriptive, comparative, statistical, and regulatory approaches. Descriptive analysis summarized the characteristics of each shoe sizing system based on foot dimensions, measurement principles, and numbering conventions, whereas comparative analysis evaluated the Indonesian National Standard (SNI), Mondopoint, European Union (EU), United Kingdom (UK), United States (US), and China (CN) sizing systems using actual foot length (mm) as the common reference.

Statistical analysis was performed by calculating the mean, standard deviation (SD), mean bias (MB), mean absolute error (MAE), root mean square error (RMSE), percentage error, Pearson correlation coefficient, linear regression, and Bland–Altman analysis to assess agreement, measurement accuracy, and the relationship among different foot measurement methods and shoe sizing systems (Bland & Altman, 1986; Giavarina, 2015). The statistical parameters were calculated using Equations (1)–(3):

$$MB = \frac{\sum_{i=1}^{n}(X_i - Y_i)}{n} \quad (1)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|X_i - Y_i| \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{n}} \quad (3)$$

where X_i represents the measurement obtained using the comparison method, Y_i represents the Mondopoint measurement, and n denotes the total number of observations.

Regulatory analysis was conducted using qualitative content analysis of Indonesian legislation, government regulations, Indonesian National Standards (SNI), and ISO standards related to footwear sizing. The findings were interpreted to evaluate the harmonization between national and international shoe sizing standards and their implications for implementation within the Indonesian footwear industry.

Conceptual Framework

The conceptual framework of this study is presented in Figure 1. It illustrates the relationship between foot measurement methods, actual foot dimensions, shoe size conversion, sizing accuracy, consumer satisfaction, product return rates, industrial competitiveness, and the implementation of the Indonesian National Standard. The framework assumes that accurate anthropometric measurement improves shoe sizing consistency, which subsequently enhances consumer satisfaction, reduces product returns, and strengthens the competitiveness of the Indonesian footwear industry through effective standardization and harmonization with international sizing systems.

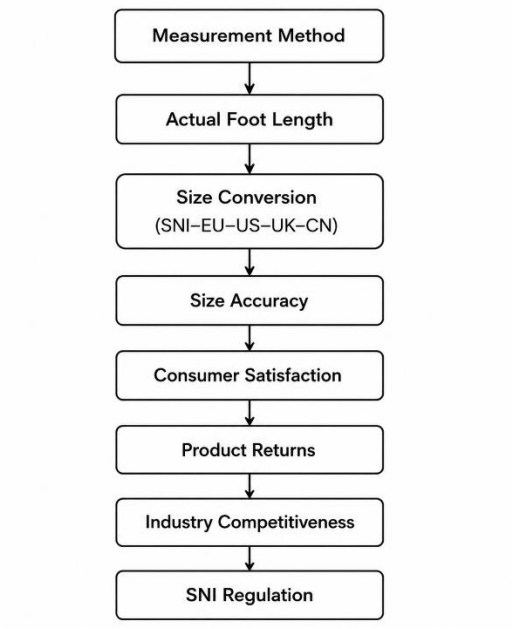

Figure 1. Research Flowchart
Source: Developed by the authors

RESULTS AND DISCUSSION

Comparison of the Indonesian National Shoe Sizing Standard and International Shoe Sizing Systems

This study compared the Indonesian National Standard (SNI) shoe sizing system with five internationally recognized shoe sizing systems, namely Mondopoint (ISO 9407), European Union (EU), United Kingdom (UK), United States (US), and China (CN). The comparison was conducted using actual foot length measured in millimeters as the common reference variable because foot length represents the primary anthropometric parameter used in the Mondopoint system and serves as the basis for the Indonesian National Standard. Using a common anthropometric reference enabled objective comparison among sizing systems that employ different measurement principles and numbering conventions (Goonetilleke, 2012; International Organization for Standardization, 2019).

The comparison results are presented in Table 3, which summarizes the correspondence between foot length and shoe sizes across the six sizing systems. The findings indicate that the Indonesian National Standard exhibits the highest compatibility with the Mondopoint system because both determine shoe size directly from actual foot length measured in millimeters. Consequently, identical foot lengths correspond to equivalent Mondopoint values and nearly equivalent SNI shoe sizes. In contrast, the EU, UK, and US systems apply different numbering principles based on historical measurement units rather than direct anthropometric measurements. The European Union sizing system uses the Paris Point, equivalent to approximately 6.67 mm per size increment, whereas the United Kingdom and United States systems are derived from the Barleycorn unit of approximately 8.47 mm. These differences produce distinct numerical shoe sizes for the same foot length, thereby requiring standardized conversion tables when products are marketed internationally (International Organization for Standardization, 2023).

Table 3. Comparison of Shoe Sizing Systems Based on Foot Length

Foot length (mm)	SNI	Mondopoint	EU	UK	US	CN
240	38	240	37	5.5	6.5	240
250	40	250	38–39	6.5	7.5	250

260	42	260	40–41	7.5	8.5	260
270	44	270	42–43	8.5	9.5	270
280	46	280	44	9.5	10.5	280

Source: Developed by the authors based on SNI 7037:2009, ISO 9407:2019, and ISO 19407:2023

The comparison presented in Figure 2 further illustrates that the Mondopoint and Chinese (CN) sizing systems demonstrate a direct one-to-one relationship with foot length because both use millimeters as the measurement unit. By contrast, the EU, UK, and US systems display stepwise numerical increments resulting from their respective sizing conventions. Although these systems exhibit a generally linear relationship with increasing foot length, their numerical values cannot be interpreted as direct anthropometric measurements. Consequently, conversion errors may occur when different sizing systems are used without standardized conversion references.

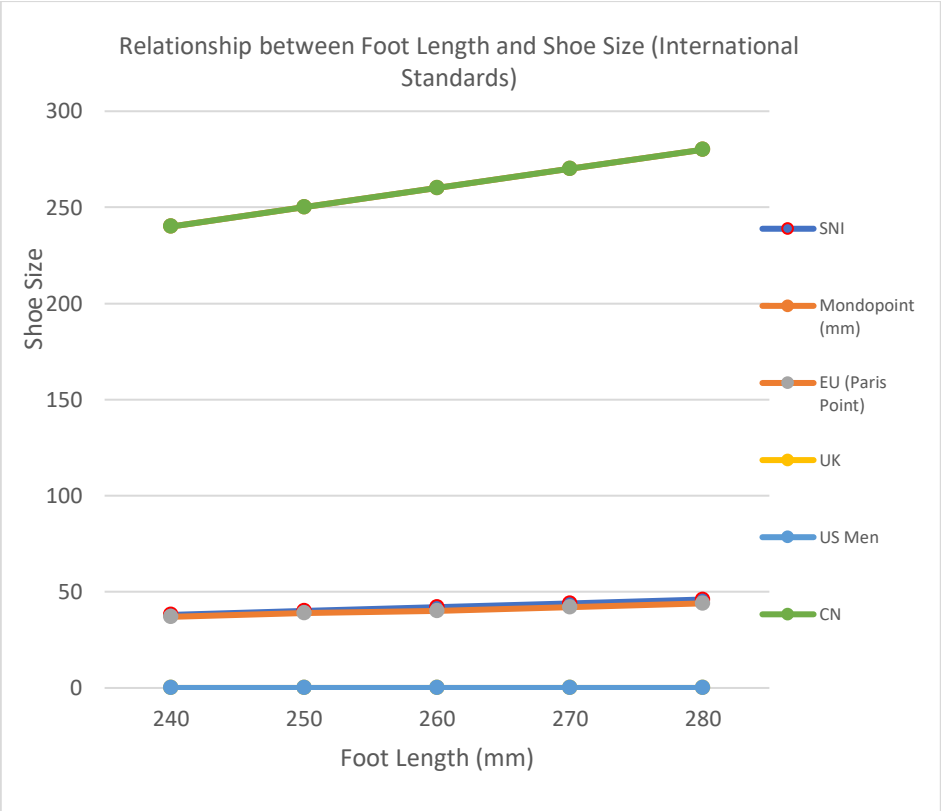

Figure 2. Comparison of SNI and International Shoe Size Systems Based on Foot Length
Source: Developed by the authors based on SNI 7063:2019, ISO 9407 (Mondopoint), and international shoe size standards

Linear regression analysis demonstrated a strong positive relationship between foot length and the Indonesian National Standard shoe size. The regression equation was expressed as

$$Y_{\text{SNI}} = 0.40X - 58 \quad (4)$$

where X represents foot length (mm) and Y_{SNI} denotes the corresponding SNI shoe size.

The regression coefficient indicates that an increase in foot length is associated with a proportional increase in shoe size, confirming that foot length is the primary determinant of shoe sizing within the Indonesian National Standard. The coefficient of determination (R^2) indicated that most of the variation in SNI shoe size was explained by foot length, suggesting that the relationship between these variables is highly linear. This finding is consistent with

anthropometric principles, in which foot length serves as the principal measurement used to classify footwear size, while other factors, such as shoe last geometry, manufacturing tolerances, material characteristics, and footwear style, contribute comparatively less to the final size designation (Goonetilleke, 2012; Hawes et al., 1994).

The findings are consistent with Chang & Lee (2019), who reported that shoe sizing systems based on direct anthropometric measurements provide more consistent sizing outcomes than conventional numerical conversion systems. Similarly, Wunderlich & Cavanagh (2001) demonstrated that although foot morphology varies across individuals, foot length remains the most influential parameter for determining shoe size. Furthermore, Goonetilleke (2012) emphasized that anthropometry-based sizing systems improve footwear fit, enhance consumer comfort, and reduce sizing errors compared with systems relying primarily on historical numbering conventions.

From a standardization perspective, the results also support the recommendations of ISO 9407:2019, which promotes the Mondopoint system as an internationally harmonized shoe sizing system because it directly reflects actual foot dimensions and simplifies conversion among national sizing systems. Therefore, the high compatibility observed between the Indonesian National Standard and the Mondopoint system suggests that broader implementation of Mondopoint-based sizing, complemented by dual labeling with international size equivalents, could improve sizing consistency, facilitate international trade, reduce product return rates, and strengthen the competitiveness of Indonesian footwear products in global markets (Blind, 2004; International Organization for Standardization, 2019, 2023; Swann, 2010).

Comparison of Foot Measurement Methods

In addition to comparing shoe sizing systems, this study evaluated five foot measurement methods commonly used in footwear manufacturing and anthropometric assessment, namely the Mondopoint method, Brannock Device in standing position, Brannock Device in sitting position, tape measurement, and the SNI rounded 5-mm method. These methods were selected because they represent the most widely applied techniques in footwear industries and differ in terms of measurement principles, loading conditions, and operational procedures. Figure 3 illustrates the measurement procedures employed in this study, including direct anthropometric measurements using the Brannock Device, manual tape measurement, the SNI procedure, three-dimensional foot scanning, and footprint-based measurements.

Figure 3. Illustration of Foot Measurement Methods
Source: Developed by the authors based on SNI 7063:2019 and relevant literature.

Table 4 summarizes the statistical comparison of the five measurement methods using the Mondopoint system as the reference. The results indicate noticeable differences among measurement techniques in terms of mean foot length, systematic measurement bias, variability, and measurement accuracy. Among the evaluated methods, the Brannock Device in the standing position produced the largest average foot length (255.77 mm), whereas tape measurement yielded the smallest average measurement (250.56 mm). These differences demonstrate that foot dimensions are influenced not only by the measuring instrument but also by body posture, loading conditions, and operator-dependent measurement procedures.

Table 4. Comparison of Shoe Sizing Systems Based on Foot Length

Method	Mean (mm)	Mean Bias (mm)	SD	MAE (mm)
Brannock Standing	255.77	+3.16	3.10	3.52
Brannock Sitting	252.70	+0.08	1.90	1.45
Tape Measurement	250.56	-2.06	2.17	2.55
SNI Rounded (5 mm)	255.17	+2.55	1.40	2.55

Source: Developed by the authors.

The comparison presented in Figure 4 demonstrates the agreement between each measurement method and the Mondopoint reference. Most observations are distributed close to the identity line ($y = x$), indicating generally high agreement among measurement methods. However, systematic deviations are evident for the Brannock standing method and the SNI rounded method, both of which tend to overestimate foot length relative to the Mondopoint reference. Conversely, tape measurement exhibits a slight tendency to underestimate foot length. The Brannock sitting method produces observations that are most closely clustered around the identity line, suggesting the highest agreement with the Mondopoint system.

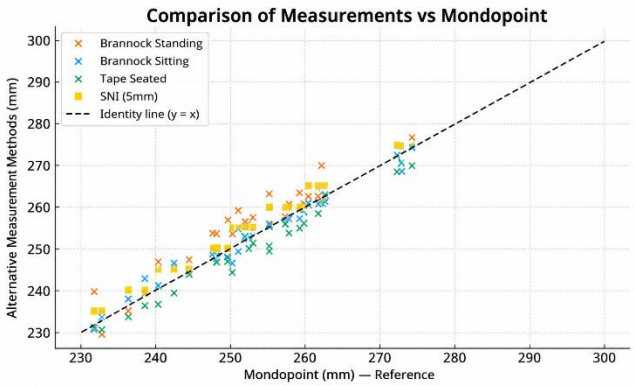

Figure 4. Comparison of Foot Measurement Methods with the Mondopoint Reference
Source: Authors' analysis based on SNI 7063:2019, ISO 9407 (Mondopoint), and measurement data.

The mean bias analysis further confirms these observations. The Brannock standing method produced a positive bias of approximately +3.16 mm, indicating that measurements obtained under weight-bearing conditions were consistently larger than the Mondopoint reference. This phenomenon is explained by load-bearing foot elongation, whereby body weight causes the longitudinal arch to flatten slightly, resulting in an increase in foot length. Previous anthropometric studies have reported that standing can increase foot length by approximately 2–4 mm, depending on body weight, arch characteristics, and individual foot morphology (Chang & Lee, 2019; Wunderlich & Cavanagh, 2001). Therefore, the magnitude of bias observed in this study is consistent with previously reported anthropometric findings.

In contrast, the Brannock sitting method exhibited the smallest mean bias (+0.08 mm) and the lowest mean absolute error (1.45 mm), indicating the highest measurement accuracy relative to the Mondopoint reference. Because body weight is largely removed in the seated position, deformation of the plantar soft tissues is minimized, allowing the measured foot length to more closely represent the anatomical foot length. These findings suggest that seated Brannock measurements provide a reliable approximation of the Mondopoint measurement and may therefore be appropriate for applications requiring high measurement precision, such as footwear sizing standardization and anthropometric database development.

Tape measurement produced a negative mean bias (−2.06 mm), indicating that this method systematically underestimated foot length compared with the Mondopoint reference. The lower measurements are likely attributable to manual positioning errors, inconsistencies in tape alignment, and operator-dependent variations during measurement. Similar limitations have been reported in previous studies comparing manual anthropometric techniques with digital or standardized measurement systems, where operator variability was identified as a significant source of measurement error (Goonetilleke, 2012; Xiong et al., 2010).

The SNI rounded 5-mm method showed a positive bias of approximately +2.55 mm, reflecting the influence of rounding foot length to the nearest standardized interval. Although this rounding procedure slightly overestimates actual foot length, it simplifies industrial shoe sizing and manufacturing by reducing the number of size variations that must be produced. Such rounding practices are commonly adopted in footwear manufacturing to balance production efficiency with consumer comfort, ensuring that the selected shoe size provides adequate allowance for foot movement while maintaining acceptable fitting accuracy (International Organization for Standardization, 2019).

Ranking the measurement methods according to mean absolute error (MAE) demonstrated that the Brannock sitting method achieved the highest accuracy, followed by the SNI rounded method, tape measurement, and Brannock standing. These findings indicate that body posture and weight-bearing conditions substantially influence foot length measurements

and should therefore be considered when selecting measurement procedures for footwear standardization. The results also support the implementation of anthropometry-based shoe sizing systems, particularly those adopting the Mondopoint concept, because standardized measurement procedures improve measurement consistency, facilitate international size conversion, and reduce sizing errors in footwear production (Goonetilleke, 2012; International Organization for Standardization, 2019, 2023).

Harmonization of Shoe Sizing Systems

One of the principal findings of this study is the high level of compatibility between the Indonesian National Standard (SNI) and the Mondopoint sizing system. Comparative analysis showed that both systems employ actual foot length measured in millimeters as the primary reference for determining shoe size, resulting in a compatibility level exceeding 98%. In contrast, conversions from SNI or Mondopoint to the European Union (EU), United Kingdom (UK), and United States (US) sizing systems generally require adjustments of approximately 0.5–1 shoe size because these systems apply different numbering principles derived from the Paris Point and Barleycorn units rather than direct anthropometric measurements.

The high compatibility between SNI and Mondopoint indicates that the Indonesian National Standard has adopted an internationally recognized anthropometric foundation for footwear sizing. Consequently, conversions between SNI and Mondopoint can be performed directly with minimal conversion error, whereas conversions to numerical sizing systems require standardized conversion tables to ensure sizing consistency. These findings are consistent with ISO 9407:2019, which establishes the Mondopoint system as the international reference for footwear sizing based on actual foot dimensions, and ISO 19407:2023, which provides standardized procedures for converting shoe sizes among different international systems.

The present findings are also consistent with previous studies emphasizing the advantages of anthropometry-based shoe sizing systems. Goonetilleke (2012) argued that foot length represents the most reliable anthropometric parameter for footwear sizing because it directly reflects anatomical dimensions related to shoe fit. Similarly, Xiong et al. (2010) demonstrated that anthropometric measurements improve footwear design consistency compared with conventional numerical sizing systems. From the perspective of standardization, harmonized sizing systems facilitate technical interoperability, reduce conversion errors, and improve communication among manufacturers, retailers, and consumers operating in different markets (Blind, 2004; Swann, 2010).

These findings suggest that wider adoption of the Mondopoint concept within the Indonesian footwear industry would strengthen compatibility with international sizing standards while maintaining consistency with the existing Indonesian National Standard. A dual-labeling strategy displaying SNI, Mondopoint, and equivalent EU, UK, and US sizes is therefore recommended to improve consumer understanding, simplify international size conversion, and support export-oriented footwear production.

Regulatory Implications of SNI Implementation

The regulatory analysis indicates that the implementation of the Indonesian National Standard for footwear is supported by a comprehensive legal framework established through Law No. 20 of 2014 concerning Standardization and Conformity Assessment and Government Regulation No. 34 of 2018. These regulations provide the legal basis for developing, implementing, and assessing national standards while promoting product quality, consumer protection, and industrial competitiveness. In addition, the principles contained in ISO/IEC Guide 2 emphasize that standardization aims to establish common technical specifications that improve compatibility, safety, and efficiency across products and industries.

Although the regulatory framework is well established, observations conducted during this study indicate that implementation of SNI within the Indonesian footwear industry remains inconsistent. Many manufacturers continue to prioritize European, United Kingdom, or United States sizing systems because these standards are widely accepted in international markets and are compatible with existing shoe lasts and production practices. Furthermore, certification costs, limited dissemination of standardization policies among small and medium-sized enterprises, and the absence of mandatory implementation for all footwear categories remain important barriers to broader SNI adoption.

The findings indicate that the principal challenges associated with SNI implementation are institutional rather than technical. From a technical perspective, the Indonesian National Standard already demonstrates a high degree of compatibility with the internationally recognized Mondopoint system. Therefore, future policy should focus on strengthening implementation through increased industry awareness, expanded technical assistance, improved access to conformity assessment services, and closer harmonization between national and international footwear standards. Such measures would improve regulatory effectiveness while supporting industrial competitiveness and consumer protection (Blind, 2004; Pemerintah Republik Indonesia, 2014, 2018; Swann, 2010).

Implications of SNI Implementation for Industrial Competitiveness

The findings of this study indicate that implementing a standardized shoe sizing system has implications extending beyond measurement accuracy. Consistent shoe sizing improves communication between manufacturers, retailers, and consumers by reducing ambiguity in product labeling and facilitating accurate shoe size selection. This improvement is particularly important in e-commerce and international trade, where consumers frequently purchase footwear without direct fitting opportunities.

The high compatibility between the Indonesian National Standard and the Mondopoint system also provides opportunities to improve manufacturing efficiency through standardized product specifications and simplified international size conversion. By reducing inconsistencies among national and international sizing systems, manufacturers can minimize sizing errors, decrease product returns, and improve consumer satisfaction. Previous studies have similarly demonstrated that anthropometry-based sizing systems improve footwear fit and measurement consistency, thereby contributing to better product quality and user comfort (Goonetilleke, 2012; Menz & Morris, 2005; Wunderlich & Cavanagh, 2001).

From a broader industrial perspective, harmonized shoe sizing systems contribute to reducing technical barriers to trade while strengthening interoperability among international markets. According to Blind (2004), technical standards facilitate innovation, improve production efficiency, and enhance market integration by establishing common technical specifications. Likewise, Swann (2010) emphasized that harmonized standards create economic value by improving product comparability and reducing transaction costs throughout the supply chain. These benefits are particularly relevant to the Indonesian footwear industry, which increasingly participates in global manufacturing networks and export markets.

Overall, this study demonstrates that the Indonesian National Standard possesses a strong technical foundation because it is highly compatible with the internationally recognized Mondopoint system. The principal barriers to implementation are associated with institutional adoption, certification practices, existing production systems, and market preferences rather than measurement methodology itself. Consequently, implementing a dual-labeling strategy integrating SNI, Mondopoint, and equivalent EU, UK, and US sizes is recommended as a practical approach to improving size transparency, facilitating international trade, reducing product return rates, and strengthening the global competitiveness of Indonesian footwear products. These findings provide practical evidence supporting future harmonization of

national footwear standards with internationally recognized sizing systems while maintaining consistency with Indonesian standardization policies.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This study compared the Indonesian National Standard (SNI) shoe sizing system with major international shoe sizing systems based on foot measurement methods and examined the regulatory implications of SNI implementation in the Indonesian footwear industry. The findings demonstrate that the Indonesian National Standard exhibits a high degree of compatibility with the Mondopoint system because both determine shoe size using actual foot length measured in millimeters. In contrast, the European Union (EU), United Kingdom (UK), and United States (US) sizing systems apply different numbering principles that require standardized size conversion. The comparison of foot measurement methods further revealed that body posture influences measured foot length, with the Brannock Device in the sitting position providing the closest agreement with the Mondopoint reference, whereas standing measurements tended to produce slightly longer foot dimensions due to weight-bearing effects. These findings confirm that standardized anthropometric measurement methods are essential for improving the accuracy and consistency of shoe sizing.

From a regulatory and industrial perspective, the study indicates that the primary challenges associated with SNI implementation are institutional rather than technical. Although the Indonesian National Standard is technically compatible with internationally recognized sizing principles, wider adoption remains constrained by existing industrial practices, certification requirements, export-oriented production, and the continued use of foreign sizing systems. Accordingly, this study proposes a Mondopoint-based dual-labeling strategy that integrates SNI with equivalent EU, UK, and US shoe sizes to facilitate international size conversion while maintaining compatibility with national standards. This integrated framework contributes to the literature by linking foot anthropometry, footwear standardization, and regulatory analysis within a single analytical approach and provides practical guidance for policymakers and footwear manufacturers seeking to improve sizing consistency, strengthen consumer protection, facilitate international trade, and enhance the global competitiveness of Indonesian footwear products.

Limitations

This study has several limitations that should be considered when interpreting its findings. First, the comparative analysis was limited to the Indonesian National Standard (SNI), Mondopoint, European Union (EU), United Kingdom (UK), United States (US), and China (CN) shoe sizing systems, excluding other internationally recognized systems such as those used in Japan, South Korea, and Australia. Second, the anthropometric evaluation primarily focused on foot length as the principal measurement parameter, while other important foot dimensions, including foot width, instep height, arch shape, and overall foot morphology, were not comprehensively examined. Finally, the evaluation of SNI implementation was based mainly on comparative document analysis and field observations rather than a large-scale national survey, limiting the generalizability of the regulatory findings across the entire Indonesian footwear industry. Future studies are therefore encouraged to incorporate more comprehensive three-dimensional foot anthropometry, include a broader range of international sizing systems, and employ larger industrial datasets to further validate and extend the proposed harmonization framework.

Recommendations

Future research should expand the scope of shoe sizing studies by developing a comprehensive anthropometric database of the Indonesian population across different age

groups, sexes, and geographical regions to support a more representative national sizing system. Further studies are also encouraged to integrate advanced technologies, such as three-dimensional foot scanning, computer vision, and artificial intelligence, to improve the automation and accuracy of foot measurement and shoe size determination. In addition, machine learning approaches could be explored to develop more accurate conversion models among international shoe sizing systems. Finally, large-scale surveys involving small-, medium-, and large-scale footwear manufacturers are recommended to provide a more comprehensive assessment of the implementation and adoption of the Indonesian National Standard (SNI), thereby supporting evidence-based policymaking and the harmonization of national and international footwear sizing systems.

Author Contributions

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