JOURNAL LA MULTIAPP

VOL. 06, ISSUE 05 (1171-1182), 2025
DOI: 10.37899/journallamultiapp.v6i5.2369

The Influence of Material Control Systems on Remaining Materials in Structural Work

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Article Info

Article history:
Received 20 June 2025
Received in revised form 16 July 2025
Accepted 13 September 2025

Keywords:
Construction Projects
Structural Works
Construction Waste

Abstract

Materials play a crucial role in the successful execution of any construction project. However, during the construction process, a significant amount of material waste can be generated, highlighting the importance of having an effective material control system in place to help achieve project goals. This study aimed to identify the types of construction materials that are most susceptible to waste, determine the underlying causes of such waste, and propose effective preventive strategies to minimize material losses during the structural work phase 1 of the SMK-SMAK Bogor Laboratory Building 1A project. The research employed a descriptive method by analyzing data collected through direct field observations and structured questionnaires. The findings were further examined using Kendall's Concordance Test to evaluate the consistency of the data, while the Spearman Rank Correlation Test was used to assess the relationship between the percentage of leftover structural materials and the corresponding preventive measures. Based on the study's findings, bending wire used in reinforcement work was identified as the material with the highest level of waste compared to other construction materials. This was primarily due to its tendency to rust easily when stored improperly, rendering it unusable. The most significant factor contributing to material waste on this project was inadequate material storage practices. The research concluded that planning material procurement accurately according to project needs is a highly effective solution for minimizing leftover materials.

Introduction

Bogor City, located in West Java Province, Indonesia, is a city located approximately 59 kilometers south of Jakarta and is an enclave of Bogor Regency. The rapid growth of the education sector in this city has driven an increase in the number of construction projects. The construction of educational buildings is one of the initiatives of the Bogor City Government to strengthen the quality and increase educational facilities to meet the needs of the community (Iwan et al., 2025; Wamaungo & Kamil, 2024; Maryanti, 2017). One of the educational institutions involved in this development is SMK-SMAK Bogor, which is under the auspices of the BPSDMI Ministry of Industry. This school is currently working to improve the quality of vocational education in the industrial sector through the construction of a new building complex. The location of the school, which was previously in the Ciheuleut area, will be moved to Tanah Baru, Bogor, with a total land area of approximately 35,000 m². This new area is designed to support teaching and learning activities, laboratory practices, and extracurricular activities for up to 1,200 students, and will be equipped with facilities such as a viewing deck and retention pond (Dewi & Sembiring, 2022; Stroupe & Carlone, 2022).

ISSN: 2716-3865 (Print), 2721-1290 (Online)

In the context of development, project management plays an important role as a systematic approach in planning, implementing, supervising, and completing projects with efficiency and effectiveness (Klojcnik et al., 2018; Al-Nakeeb et al., 2023; Ahmed, 2024; Kerzner, 2002). The main objective of project management is to achieve the final results according to the target within the constraints of time, budget, and available resources. One important element in project management is material management, which directly affects the aspects of cost, quality, and construction implementation time (Melly et al., 2024; Parsamehr et al., 2023; Pham & Peansupap, 2024). However, in construction projects such as the construction of the SMK-SMAK Bogor Laboratory Building 1A, the control of construction material waste is still lacking. This can be seen from the large amount of remaining material such as pieces of wire, wood, plywood, iron, and other materials when the project is completed (Stark & Cai, 2021; Sandberg et al., 2023). Material waste can be defined as building materials that exceed needs, in a remaining condition, scattered, or damaged so that they can no longer be used properly. The factors causing material waste are very diverse, starting from the design planning stage, selection of material sources, handling in the field, implementation of work, to waste from work (Hidayat & Suripto, 2019; Ahmadzadeh et al., 2023; Bajjou & Chafi, 2022).

This remaining material is basically part of the material that is not utilized during the construction process and does not become part of the final building structure. Therefore, the greater the amount of remaining material, the lower the level of efficiency of material use in the project (Maukar et al., 2023; Purchase et al., 2021; Carrara et al., 2023; Porzio & Scown, 2021). There are still few studies that specifically examine the types of materials that often experience waste, especially in structural work. In addition, there are not many studies that trace the main causes of material waste and preventive measures that can be taken to overcome it. Therefore, a special study is needed that identifies material waste in structural work, analyzes its main causes, and offers relevant solutions in the context of the construction project of the 1A SMK-SMAK Bogor Laboratory Building.

Methods

This study adopts a survey method by collecting primary data through a structured questionnaire developed based on real field conditions (Sugiyono, 2022). The research focuses on stage 1 structural work of the Laboratory 1A construction project at SMK-SMAK Bogor. Subjects include individuals directly involved in project execution, such as field implementers, structural experts, supervisors, logistics, and warehouse personnel. Both primary and secondary data were used: primary data was gathered through observation and questionnaires, while secondary data came from records of material purchases and usage. A purposive sampling technique was applied, involving 37 respondents considered representative of the studied phenomenon.

The questionnaire was constructed based on relevant theories and prior studies and consisted of four sections: general information, residual material percentage, causes of material waste, and preventive actions (Sugiyono, 2022). Responses were measured using percentage and frequency scales. Validity testing ensured the accuracy of item measurements, while reliability was tested using Cronbach's Alpha to assess internal consistency. Data analysis was conducted using SPSS with Kendall's W Concordance and Spearman's correlation tests. A non-parametric statistical approach was used, given the ordinal and perception-based nature of the data, making it suitable for the context of this study.

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Results and Discussion

Respondent Characteristics

The characteristics of the respondents influence the material waste control system in structural work in the construction project of the Bogor SMK-SMAK educational building. Of the total 37 respondents involved, the majority were between 20 and 30 years old with a percentage of 54.05%, followed by respondents aged 31–40 years as many as 32.43%, and the rest were over 40 years old as many as 13.52%. In terms of education level, most respondents had a Bachelor's degree (S1), which was 27 people or 72.97%. Furthermore, respondents with a Diploma 3 (D3) education background numbered 5 people (13.52%), and 3 high school graduates (8.11%). Job position also contributed to the research results. The largest number of respondents came from the logistics and warehouse divisions, with 7 people each (18.92%), then project supervisors with 5 people (13.51%), and Quantity & Quality Inspectors with 4 people (10.80%). When viewed from the length of work experience, the majority of respondents have work experience of less than 5 years (41.54%), followed by those who have worked for 5-10 years (32.43%), and 10-15 years (21.62%). As for the number of projects they have handled, the majority of respondents were recorded as only being involved in less than 5 projects (48.65%), then as many as 32.43% have worked on 5-10 projects, and the remaining 16.22% have been involved in 10-15 projects.

Material Remains in Structural Work

The construction project that is the focus of this study is the structural work stage 1 of Laboratory 1A of the SMK-SMAK Bogor Education Building. The stages of the structural work consist of formwork, reinforcement, and casting, each of which has its own material characteristics and work methods (Kumendong et al., 2024). To identify potential waste during project implementation, a descriptive analysis was conducted on the distribution and level of shrinkage of materials that were lost, wasted, or could not be reused in each type of structural work. There are 9 types of materials analyzed based on work groups. In formwork work, there are three main types of materials, namely wood, plywood, and nails. In reinforcement work, the materials used are U-42 reinforced concrete and bending wire. Meanwhile, in casting work, the materials studied include ready-mix concrete, cement, sand, and split stone.

Table 1. Remaining Materials from Structural Work

Structural Work	Material Type	Unit	N	Min	Max	Mean	Std. Dev	Rank
Formwork	Wood	/m	37	1 %	2 %	1.19 %	0.397	6
Formwork	Plywood	/sheet	37	2 %	3 %	2.27 %	0.450	2
Formwork	Nails	/Kg	37	1 %	2 %	1.11 %	0.315	7
Reinforcement	U-42 concrete iron	/Batang	37	1 %	2 %	1.08 %	0.277	8
Reinforcement	Wire binding	/Roll	37	2 %	3 %	2.43 %	0.502	1
Casting	Ready mix concrete	/Mixer	37	1 %	2 %	1.03 %	0.164	9
Casting	Cement	/Sak	37	1 %	4 %	1.65 %	0.716	5
Casting	Sand	/Rit	37	1 %	5 %	2.03 %	0.957	4
Casting	Split	/Rit	37	1 %	4 %	2.05 %	0.848	3

Source: Author's processing, 2025

Based on the data in Table 1 analyzed using SPSS software, it is known that the type of material with the highest average (mean) waste is the bending wire in the reinforcement work, which is 2.43%, making it the material that experiences the most waste among other materials.

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This is because the bending wire is more susceptible to rust during the storage and use process (Liman & Sulistio, 2020). In the next position is plywood from formwork work with a mean of 2.27%, followed by split (2.05%), sand (2.03%), and cement (1.65%). Meanwhile, other materials such as wood (1.19%), nails (1.11%), reinforced concrete (1.08%), and ready-mix concrete (1.03%) show lower waste. The management system applied to this construction project is good and appropriate in the process of procurement, storage, distribution and calculation of material needs. Construction materials require appropriate handling so that the materials used can be in accordance with the quantity, quality and fixed time (Mokosuli et al., 2023; Purchase et al., 2021; Peng et al., 2023).

The average represents the amount of material waste in percentage, where the higher the mean value, the greater the waste that occurs. The highest standard deviation is found in sand (0.957) and split (0.848) materials, which indicates the diversity of answers from respondents, or in other words, shows a high level of variation in waste in both materials between projects. In contrast, low standard deviations were found in ready-mix concrete (0.164) and reinforced concrete (0.277), indicating consistency in respondents' answers regarding the remaining materials. Materials such as wire mesh, plywood, split, and sand are prone to waste in the implementation of structural work. Meanwhile, materials with low levels of waste such as ready-mix concrete, reinforced concrete, nails, and wood indicate that control over their use is quite good. Special attention is needed for materials with high deviations such as sand and split, because this indicates that the level of efficiency is very dependent on project management in the field. Construction waste is included in the category of Direct waste, namely the remaining material that arises in the project because it is damaged and no longer used (Nasikhin & Triarso, 2023).

Table 2. Results of Kendall's W Coefficient of Concordance test on the percentage of residual material for structural work

Statistik	Value
N	37
Kendall's W	0.595
Chi-Square (χ^2)	176.150
df	8
Asymp. Sig. (p-value)	0.000

Source: Author's processing, 2025

The Kendall's Coefficient of Concordance (Kendall's W) test presented in Table 2 was used to measure the level of agreement between assessors regarding waste in structural work. The test results showed a Kendall's W value of 0.595, which is in the range of 0 to 1. The closer to 1, the stronger the agreement achieved. This value of 0.595 indicates a fairly strong agreement between respondents in assessing the level of waste in structural work. In addition, the significance value of Asymp. Sig. of 0.000 (less than 0.05) indicates that this agreement is statistically significant, so it can be concluded that the respondents have a meaningful assessment of waste in structural work.

Causes of Material Waste in Structural Work

Many factors can cause material waste, including design factors, material procurement, material handling, implementation, residual, and other factors (Nawawi et al., 2021). Descriptive analysis revealed eighteen factors causing material waste in structural work with varying levels of influence. Based on Table 3, the factor with the highest average score is improper material storage (mean = 4.22), followed by rusty material due to being stored for too long (mean = 4.03). This shows that problems in material management and storage are the main causes of material waste in construction projects. Storage that is not in accordance with standards can cause damage to the material, such as rust, so that the material can no

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longer be used. In addition, the factor of material cutting waste that cannot be reused also has a high mean value (4.00), indicating that material scraps from the cutting process also contribute to material waste.

Table 3. Incidents Causing Material Residues from Structural Work

Event Causes of Leftover Material	N	Mean	Std. Dev	Min	Max	Rank
Unusable cutting waste	37	4.00	0.333	3	5	3
Improper installation method	37	2.92	0.547	2	4	10
Improper dismantling method	37	2.22	0.417	2	3	14
Using low-quality materials	37	1.97	0.287	1	3	18
Errors made by workers	37	2.81	0.397	2	3	11
Insufficient supervision	37	3.57	0.502	3	4	6
Not planning material usage properly	37	3.24	0.548	2	4	9
Wasted materials	37	2.27	0.608	2	4	13
Unskilled workers	37	2.51	0.559	1	3	12
Materials rust due to being stored for too long	37	4.03	0.499	2	5	2
Improper material storage	37	4.22	0.672	2	5	1
Intentionally or unintentionally throwing or discarding materials	37	2.03	0.372	1	3	16
Design changes	37	2.03	0.372	1	3	17
Orders that do not match specifications	37	3.30	0.777	1	4	7
Estimation errors	37	3.95	0.524	3	5	4
Complicated building shapes	37	2.05	0.405	1	4	15
Changes in material specifications	37	3.27	0.508	3	5	8
Ordering materials in excess of requirements	37	3.95	0.405	3	5	5

Source: Author's processing, 2025

Other factors that have high average scores are estimation errors and ordering materials in excess of requirements, both of which have a mean value of 3.95. Meanwhile, several factors that have low mean values include the use of low-quality materials (mean = 1.97), inappropriate dismantling methods (mean = 2.22), and the act of throwing or discarding materials intentionally or unintentionally, and design changes (mean = 2.03 each). These factors with low mean values are considered less influential by respondents in causing material waste. The standard deviation values recorded in the descriptive statistics for the factors causing material waste are relatively small for almost all factors, indicating that the respondents' perceptions are quite uniform and consistent with each factor. The majority of respondents gave assessments that were not too different from each other.

Table 4. Results of the Kendall's W Coefficient of Concordance test on the Cause of Material Remaining in Structural Work

Test Statistics	
N	37
Kendall's Wa	0.745
Chi-Square	468.714
Df	17
Asymp. Sig.	**0.000**

Source: Author's processing, 2025

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Kendall's Concordance Test in Table 4 shows a coefficient of agreement (Kendall's W) of 0.745, indicating a strong level of agreement among respondents in assessing the factors causing waste material. The Chi-Square value of 468.714 with a degree of freedom (df) of 17 and an asymptotic significance of 0.000 (<0.05) shows significant results. Thus, it can be concluded that there is a strong and meaningful agreement among respondents regarding the assessment of the factors causing waste material in structural work. The identification of these waste-causing factors is considered quite accurate and can be used as a basis for developing improvement strategies.

Preventive Measures for Waste Materials in Structural Work

The implementation of construction project work starts from the planning stage which includes data collection, research/investigation, feasibility studies, physical planning to the construction implementation stage in the field and work supervision (Pertiwi et al., 2019). Efforts to reduce waste materials in structural work are carried out by identifying various preventive measures that can be implemented effectively. Material needs planning is intended so that in the implementation of the work, the use of materials becomes efficient and effective so that there are no problems due to the unavailability of materials when needed (Putra et al., 2024). These actions aim to increase the efficiency of material use, reduce losses due to waste, and support the sustainability of construction projects. Based on data from respondents, a descriptive analysis was carried out to understand the priorities and perceptions of these preventive measures, which were then further analyzed using a test of harmony of opinion with the Kendall's Coefficient of Concordance method.

Table 5. Precautions for Remaining Materials from Structural Work

Preventive measure	N	Mean	Std. Dev	Min	Max	Rank
Minimize errors in cutting materials	37	3.76	0.548	2	4	4
Supervise and guide workers	37	2.70	0.520	2	4	10
Good and accurate material specifications	37	3.97	0.372	3	5	3
Improve coordination between project personnel	37	2.57	0.502	2	3	12
Plan material cutting properly	37	3.14	0.585	2	4	8
Improve material storage quality	37	3.97	0.499	3	5	2
Plan material ordering according to needs	37	4.27	0.652	3	5	1
Improve worker awareness in handling materials	37	3.08	0.433	2	4	9
Regularly check the quantity and volume of materials correctly	37	2.19	0.397	2	3	14
Make plans for installing the materials used	37	3.49	0.607	2	4	6
Minimize design changes	37	2.57	0.603	2	4	11
Provide clear information and detailed images	37	2.54	0.605	2	4	13
Minimize changes in material specifications	37	3.68	0.530	3	5	5
Monitor work	37	3.24	0.830	2	5	7

Source: Author's processing, 2025

The results of the descriptive analysis in Table 5 show that the preventive action with the highest average score is planning material orders according to needs (mean = 4.27). This

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indicates that the majority of respondents agree that proper material requirements planning is the main step to reduce material waste in structural projects. Two other actions that also received high scores were selecting good and accurate material specifications and improving the quality of material storage (both with a mean = 3.97), which emphasizes the importance of using standard materials and managing storage to avoid damage or loss of materials. Meanwhile, actions such as checking the quantity and volume of materials periodically (mean = 2.19), providing clear information and detailed drawings (mean = 2.54), and improving coordination between project personnel (mean = 2.57) received lower average scores. Although these three things remain important, respondents considered that their contribution to preventing material waste was not as great as other factors. In addition, the relatively small standard deviation values for most factors, especially for actions related to good and accurate material specifications (Std. Dev = 0.372), indicate that respondents' perceptions regarding the importance of these factors are quite consistent.

Table 6. Results of Kendall's W Coefficient of Concordance test on Preventive Actions for Remaining Materials in Structural Work

Test Statistics	
N	37
Kendall's Wa	0.579
Chi-Square	278.510
Df	13
Asymp. Sig.	0.000
a. Kendall's Coefficient of Concordance	

Source: Author's processing, 2025

Kendall's Concordance Test shows a Kendall's W value of 0.579 with a significance level of 0.000. Because the W value is close to 1, this indicates a fairly strong alignment among respondents in assessing the importance of each waste material prevention action listed in Table 6. With a significance value below 0.05, it can be concluded that the agreement of respondents' opinions regarding the preventive actions that must be taken is significant. The priority of this action can then be used as a solid basis for improving waste material management practices in the field. For the correlation between the causes of waste material and waste material prevention actions in structural work, the Spearman's rho analysis in Table 7 shows a correlation coefficient of 0.373 with a significance of 0.023 ($p < 0.05$). This positive correlation indicates a unidirectional relationship between the causes of waste material and the implementation of preventive actions. This means that the more causes of waste material identified, the higher the preventive efforts implemented. Because the significance value is below 0.05, this relationship is declared significant. However, with a correlation value of 0.373 which is in the low to medium category, the relationship does exist but is not very strong.

Table 7. Spearman Correlation of Causes of Waste Material with Waste Material Prevention Actions in Structural Work

Correlations	**Causes of Leftover Material**	**Waste Material Prevention**
Spearman's rho		
Causes of Leftover Material	Correlation Coefficient: 1.000	Correlation: 0.373*
	Sig. (2-tailed):	Sig. (2-tailed): 0.023
	N: 37	N: 37
Waste Material Prevention	Correlation Coefficient: 0.373*	Coefficient: 1.000

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	Sig. (2-tailed): 0.023	Sig. (2-tailed): .
	N: 37	N: 37

Source: Author's processing, 2025

From the results of the Spearman correlation test, several patterns of relationships were identified between preventive measures and the types of materials that are left over, which are summarized in Table 8 below.

Table 8. Correlation of Types of Material Left Over in Structural Work and Preventive Measures

Preventative Action	Related Materials
Minimize material cutting errors	Plywood (Formwork), U-40 Steel Rebar (Reinforcement)
Ensure accurate material specifications	Plywood (Formwork), U-40 Steel Rebar (Reinforcement), Sand (Pouring)
Improve coordination among project personnel	U-40 Steel Rebar (Reinforcement), Cement (Pouring)
Plan material cutting effectively	Binding Wire (Reinforcement), Sand (Pouring)
Improve material storage quality	Plywood (Formwork), U-40 Steel Rebar (Reinforcement), Ready-mix Concrete (Pouring)
Plan material ordering according to needs	Timber (Formwork), Plywood (Formwork), U-40 Steel Rebar (Reinforcement)
Increase worker awareness in material handling	Ready-mix Concrete (Pouring), Cement (Pouring)
Regularly check material quantity and volume accurately	Timber (Formwork), Plywood (Formwork), U-40 Steel Rebar (Reinforcement), Binding Wire, Ready-mix Concrete (Pouring), Cement (Pouring)
Minimize design changes	Timber (Formwork), Plywood (Formwork), U-40 Steel Rebar (Reinforcement)
Provide clear information and detailed drawings	Timber (Formwork), Plywood (Formwork), U-40 Steel Rebar (Reinforcement)
Minimize specification changes	Plywood (Formwork), U-40 Steel Rebar, Sand (Pouring)
Monitor work progress	Timber, Plywood (Formwork), U-40 Steel Rebar (Reinforcement), Aggregate (Pouring)

Source: Author's processing, 2025

The more material remaining, the less efficient the use of material in the project (Putri et al., 2021). Preparation of structural work includes measuring and determining work points using a total station, preparing materials and equipment such as construction, aggregate, reinforcing steel, formwork, and casting tools, and ensuring the cleanliness of work areas and ensuring be.casting is clean from water or dirt (Mahendra & Ridwan, 2023). Implementation of structural work consists of column work stages, namely: column measurement work, column construction work, column reinforcement installation, column kiting work, installation/installation of plasterwork, column casting work, plastering demolition work, maintenance work (curring) (Semita & Sucita, 2024). Based on the results of Spearman's correlation analysis with a significance level below 0.05, the relationship between the percentage of material remaining and preventive measures in the context of structural work can be explained as follows:

Formwork Work

Formwork not only functions as a temporary foundation for concrete casting, but also maintains the stability and stability of newly cast concrete. Therefore, the implementation of

ISSN: 2716-3865 (Print), 2721-1290 (Online)

concrete construction work is an important indicator that influences the time of concrete construction work (Setiyawan et al., 2023). The materials used in formwork work are wood and plywood. Dismantling of plasterwork includes removal, dismantling, cleaning, lubrication, temporary storage, and repair of the scaffolding, until it can be used again (Chaise et al., 2025). Prevention that significantly correlates with the reduction of material waste in the formwork includes accuracy in cutting materials, accuracy of material specifications, and quality of material storage. Prevention efforts in formwork work should be focused on increasing the accuracy of initial planning, accuracy in the cutting process, clarity of design, and improving the quality of material storage.

Reinforcement Work

In reinforcement work, the fabrication of reinforcement iron is carried out in a large place to place, cut, bend and assemble the reinforcement iron according to the approved working drawings (Chaise et al., 2025). Materials that have the potential to produce waste include U-40 reinforced concrete and bending wire. Design changes, unclear information on working drawings, and errors in calculating material volume also increase the amount of material waste in reinforcement work. Therefore, prevention efforts must be focused on careful planning and cutting, increasing coordination of the implementation team, and more intensive supervision of material stock and use.

Casting Work

In the casting work of reinforced concrete, structural components consider the safety, strength, stability, stiffness, durability, and function factors of a building, so that they meet the planning criteria (Kumendong et al., 2024). Materials such as sand, cement, ready-mix concrete, and split are prone to producing waste due to several factors, including inappropriate material specifications, weak coordination between workers, inappropriate material volume planning, and storage and handling of materials that do not meet standards. Worker awareness in managing casting materials also greatly affects the efficiency of material use.

Conclusion

Based on the results of observations and data analysis on the SMK-SMAK Bogor Laboratory Building 1A structure project, it was found that bending wire was the material with the highest waste (2.43%) due to its susceptibility to rust. Improper material storage is the main cause of material waste (average 4.22). And the most effective solution is planning material orders according to needs (average 4.27), because it can increase efficiency, reduce waste, and support project sustainability.

Based on the research findings, it is recommended that project management pay greater attention to proper material storage systems that meet standards and protect against damage, especially for vulnerable materials such as bending wire. Additionally, material requirement planning should be carried out carefully and matched to the actual project volume to avoid over-ordering. Efforts to enhance coordination among project teams, enforce strict supervision, and raise workers' awareness of efficient material usage are also essential to consistently implement in order to minimize material waste and improve overall construction efficiency.

Acknowledgment

The authors would like to express their deepest gratitude to Tama Jagakarsa University, particularly the Master of Civil Engineering Study Program, for the support and facilities provided throughout the course of this research. Special thanks are extended to all respondents involved in the construction project of the Laboratory Building 1A at SMK-SMAK Bogor, whose valuable time and information greatly contributed to the study. The authors also wish

ISSN: 2716-3865 (Print), 2721-1290 (Online)

to acknowledge the guidance and encouragement from academic supervisors and colleagues, whose input played a significant role in the completion of this article.

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