**Doi:**

# Designing a Pharmaceutical Supply Chain Traceability and Logistics Management Model Based on the Performance of a Resilient Green Hospital under Crisis Conditions in Greater Tehran

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**Original Article**

## Abstract

**INTRODUCTION:** This study aims to develop a pharmaceutical supply chain traceability and logistics management model grounded in the performance of a resilient green hospital operating under crisis conditions in Greater Tehran.

**METHODS:** This exploratory–analytical study is applied in terms of purpose. Given the indeterminate size of the population, a sample of 384 respondents was selected using Morgan's formula. Data were collected using standardized questionnaires, including: the Green Logistics Management questionnaire by Baah et al. (2019), the Supply Chain Traceability questionnaire by Cousins et al. (2019), the Circular Economy Practices questionnaire by Zeng et al. (2017), and the Sustainability Performance questionnaire by Agyabeng-Mensah et al. (2020).Data was analyzed and coded using SPSS and Smart PLS software.

**FINDINGS:** The results indicate a positive and significant relationship between pharmaceutical supply chain traceability, green logistics management, and the performance of resilient green hospitals under crisis conditions.

**CONCLUSION:** According to the results, enhancing pharmaceutical supply chain traceability alongside the implementation of green logistics management can significantly improve the performance and resilience of green hospitals during crisis situations.

**Keywords:** Green logistics management; Performance; Sustainability; Supply chain traceability; Resilient green hospital.

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## Introduction

The term "green supply chain traceability" refers to the global efforts of organizations to measure and minimize their adverse environmental impacts which the effective outcomes of these efforts can assist organizations in achieving sustainability while balancing environmental and economic performance. The American Reverse Logistics Executive Council (RLEC) defines green logistics as a method for understanding the environmental impacts of the logistics sector.

According to Wu and Dunn (1), green logistics is an environmentally responsible system that encompasses the implementation of "proactive" logistics procedures, such as the sourcing of raw materials, production, packaging, and distribution of goods, as well as reverse logistics procedures, including the collection and repackaging of waste for reuse.

A green hospital refers to an institution in which all processes, structures, and services are designed and managed based on environmental sustainability principles. Such hospitals aim to reduce operational costs, protect the environment, promote patient health, enhance resource productivity, and optimize energy, water, and material consumption, particularly under crisis conditions.

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Logistics refers to the practices and strategies for managing the supply chain that minimize environmental and energy footprints, focusing on the transportation of materials, waste management, packaging, and distribution.

Logistics refers to supply chain management practices and strategies that seek to reduce the environmental and energy footprint of freight distribution, with particular emphasis on material handling, waste management, packaging, and transportation (1). The Natural Resource-Based View (NRBV) further explains how green products and practices can provide organizations with strategic capabilities and positive environmental outcomes (2). Extensive research in green logistics management and the circular economy supports the NRBV framework, indicating that organizations are increasingly adapting their operations to align with environmental constraints and opportunities (3).

The Ellen MacArthur Foundation(2013) conceptualized the circular economy as a regenerative system designed to replace the traditional "end-of-life" model. This approach emphasizes waste elimination through the restorative design of materials, systems, products, and business models while incorporating renewable energy sources. In practice, circular economy principles can reduce investment risks and improve risk-adjusted returns (4).

Traceability is defined as the ability to track food, feed, animals, or substances intended for consumption across all stages of production, processing, and distribution. In 2012, GS1, the international non-profit organization responsible for global barcode standards, defined traceability data elements in its Global Traceability Standard, including the identification of the traceable item, involved stakeholders, location, time, and the specific process or event undertaken (5).

Performance measurement and performance metrics are intrinsically interconnected and should not be examined independently. Existing research confirms that performance metrics play a critical role in enabling effective measurement and evaluation processes (6).

Lee et al. (2010) investigated the drivers of technological innovation through green supply chain management and found that increased technological innovation positively influences environmental performance and production efficiency. Their findings suggest that pursuing innovation encourages the adoption of green supply chain management practices. Similarly, Lee et al. examined supply chain innovation and organizational performance in the healthcare sector, demonstrating that continuous innovation in collaboration with suppliers enhances organizational performance in large hospitals (7).

Lee et al. (2010) explored the impact of creative management practices on employee performance across multiple industries in the United States. Their results indicated that factors such as strategic partnerships, communication, and information sharing significantly improve operational performance (7).

Wisner (2006) also identified a positive and significant relationship between innovative leadership practices and organizational performance through strategic collaboration (8).

Researchers emphasize that waste generation has substantial environmental and economic consequences. Improvements in environmental performance not only reduce pollution, water consumption, solid waste, and hazardous material use but also promote material reuse and cost reduction (9).

Moreover, sustainable supply chain practices can enhance organizational competitiveness and environmental credibility, particularly when aligned with recognized environmental standards (10).

The primary objective of this study is to design a pharmaceutical supply chain traceability and logistics management model based on resilient green hospital performance in Greater Tehran. The specific objectives are as follows:

- To validate the relationship between logistics management and resilient green hospital performance.
- To validate the relationship between logistics management and green hospital practices.
- To examine the impact of green hospital practices on resilient green hospital performance.
- To investigate the mediating role of green hospital practices in the relationship between logistics management and resilient performance.
- To validate the relationship between supply chain traceability and green hospital practices.
- To examine the moderating role of supply chain traceability in the relationship between logistics management and green hospital practices.

## Methods

The present study is exploratory–analytical in terms of its purpose and seeks to develop applied knowledge within a specific research domain. With respect to data collection, the study is classified as descriptive–correlational. In terms of research approach and nature, it is causal, as it aims to examine the relationships among the study variables. The research adopts a quantitative approach, with data collected through a structured questionnaire.

The measurement instruments were adapted from previously validated questionnaires, including the Green Logistics Management questionnaire developed by Baah et al. (2019), the Supply Chain Traceability questionnaire by Cousins et al. (2019), the Circular Economy Practices questionnaire by Zeng et al. (2017), and the Sustainability Performance questionnaire by Agyabeng-Mensah et al. (2020).

Because no prior study has reported reliability coefficients for this specific combined questionnaire, reliability was assessed using Cronbach's alpha. The results of the reliability analysis are presented in Table 1.

**Table 1.** Cronbach's alpha values of the questionnaires

| Construct | Cronbach's Alpha (α) |
|---|---|
| Resilient green hospital performance | 0.939 |
| Resilient performance | 0.936 |
| Pharmaceutical supply chain traceability | 0.932 |
| Logistics management | 0.926 |

### *Reliability of the Questionnaire*

Reliability refers to the extent to which a measurement instrument produces consistent results under identical conditions, reflecting the degree of correlation between repeated measurements obtained independently from the same group of respondents. One of the most widely used methods for assessing questionnaire reliability is Cronbach's alpha coefficient. The questionnaire employed in this study was adapted from standard instruments; however, as no prior research had reported reliability values for this specific version, Cronbach's alpha was calculated for the present study. The resulting reliability coefficients for the questionnaire constructs are reported in Table 1.

### *Statistical Population and Sample*

The statistical population of this study comprised experts and specialists involved in the pharmaceutical supply chain and its logistics processes through to the completion of the operational cycle in hospitals across Tehran Province. To determine the appropriate sample size from an infinite (unknown) population, Cochran's formula for infinite populations was applied. This formula considers the confidence level, margin of error, and the estimated proportion of the target attribute within the population. Assuming a 95% confidence level ($Z = 1.96$), a margin of error of 5% ($e = 0.05$), and a population proportion of 0.5 ($p = 0.5$), the required sample size was calculated accordingly.

With respect to the educational background of the respondents, the results presented in Table 2 indicate that, among the 150 participants, the largest proportion belonged to the postgraduate education group, comprising 43 individuals (28.7%), while the smallest proportion corresponded to respondents with a diploma or lower level of education, totaling 34 individuals (22.7%).

**Table 2.** Frequency related to educational group

| Variable | Diploma & lower | Associate degree | Master's/ postgraduate | Total |
|---|---|---|---|---|
| Percentage | 22.7 | 24.0 | 43 | 100 |
| Frequency | 34 | 36 | 28.7 | 150 |

## Findings

In this section, a questionnaire was employed to measure the research variables. The instrument comprised five main constructs—green product, pollutant control, cost, environmental management, service, and quality—to assess green logistics performance, encompassing a total of 18 items. Content validity was evaluated using the Content Validity Ratio (CVR), calculated based on the assessments of 20 subject-matter experts. The reliability of the questionnaire was confirmed by a Cronbach's alpha coefficient of 0.895, indicating a high level of internal consistency. Detailed information regarding the validity and reliability of all questionnaire items is presented separately.

Responses were recorded using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Accordingly, the total score for each organization ranged from 18 to 90. Scores above 72 were classified as favorable, scores between 54 and 72 as moderate, and scores below 54 as weak.

Table 3 presents the descriptive statistics for the study variables, including the mean, median, mode, standard deviation, variance, skewness, and kurtosis of the responses. Due to space constraints, detailed statistical values are reported only in the table. The results indicate that the resilient performance variable has the highest mean value (3.0373), whereas green logistics management and supply chain traceability exhibit the lowest mean values (2.4376), suggesting lower overall scores for these constructs among the sampled respondents.

**Table 3.** Descriptive statistics of research variables

| | Resilient performance | Resilient hospital | Green logistics management | Supply chain traceability |
|---|---|---|---|---|
| Mean | 3.0373 | 2.6577 | 2.4376 | 2.4376 |
| Median | 3.0000 | 2.4000 | 2.2000 | 2.4000 |
| Mode | 3.00a | 2.00 | 1.00 | 1.00 |
| Standard deviation | 1.13478 | 1.14450 | 1.09702 | 1.05712 |
| Variance | 1.288 | 1.310 | 1.203 | 1.117 |
| Skewness | -.070 | .366 | .494 | .531 |
| Kurtosis | -.874 | -.803 | -.697 | -.268 |

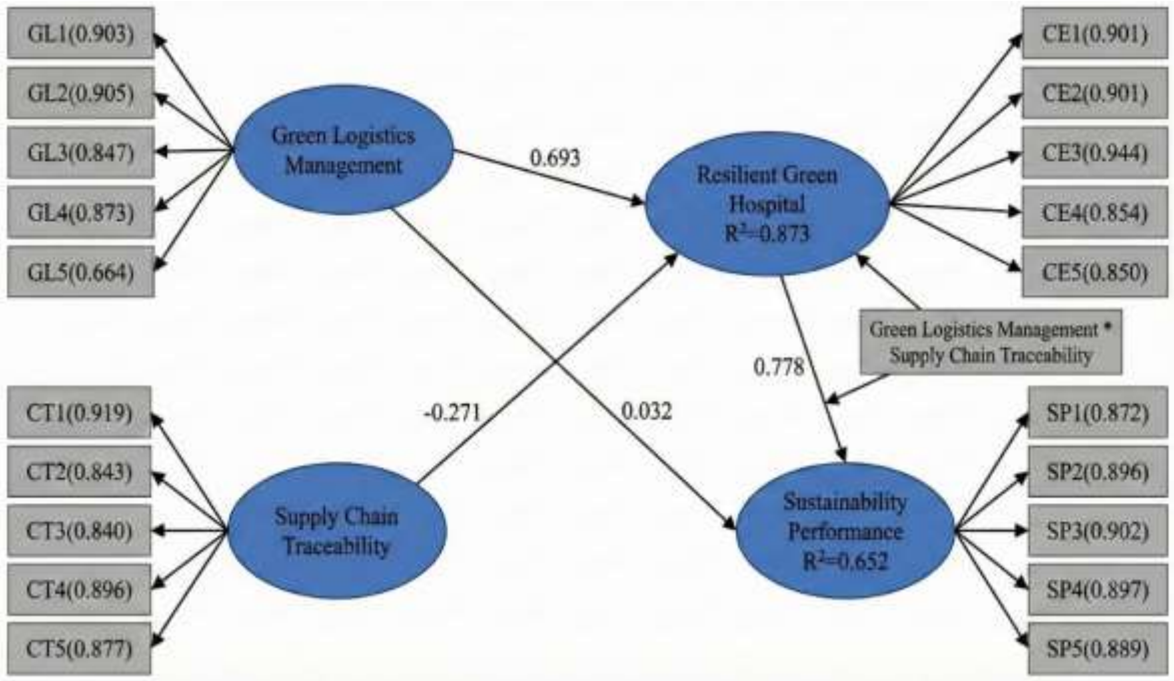


**Figure 1.** Factor loading values for the constructs and indicators of the research model

**Table 4**. Results of Cronbach's alpha, rho_A, composite reliability criteria, and AVE coefficients

| | Cronbach's alpha | rho_A | Composite Reliability (CR) | Convergent Validity (AVE) |
|---|---|---|---|---|
| Green hospital performance | 0.939 | 0.940 | 0.954 | 0.804 |
| Resilient performance | 0.936 | 0.944 | 0.951 | 0.794 |
| Supply chain traceability | 0.932 | 0.940 | 0.948 | 0.785 |
| Green logistics management | 0.926 | 0.930 | 0.944 | 0.772 |

**Table 5.** Fornell-Larcker method

| | Circular Economy Practices | Sustainability Performance | Supply Chain Traceability | Green Logistics Management |
|---|---|---|---|---|
| Circular Economy Practices | 0.897 | | | |
| Sustainability Performance | 0.807 | 0.891 | | |
| Supply Chain Traceability | 0.706 | 0.724 | 0.886 | |
| Green Logistics Management | 0.627 | 0.753 | 0.805 | 0.879 |

***Model Fit Assessment***

To evaluate the adequacy of the measurement models, three criteria were applied: reliability, convergent validity, and discriminant validity. As illustrated in Figure 1, all measurement items exhibit factor loading coefficients greater than 0.4, indicating an acceptable level of item reliability and supporting the suitability of the measurement model.

***Reliability and Validity of the Measurement Model***

To assess the model fit, the factor loadings of the research items are first examined. The factor loading, or lambda, is essentially a correlation coefficient between the latent variables and the observable variables in a measurement model. This coefficient determines how much of the variance of the observable variables is explained by the latent variable, and since it is a correlation coefficient, it must be statistically significant. The factor loading for each item must be higher than 0.4. Figure 4-5 shows the factor loadings of various items. As observed in the figure above, the factor loading coefficient of all items is higher than 0.4.

***A) Cronbach's alpha, Dillon-Goldstein's rho index, and composite reliability***

The coefficients of "Cronbach's alpha" and "Dillon-Goldstein's rho" (rho_A) are two other factors in evaluating the internal consistency reliability of the model, which support the internal consistency validity of the items. The coefficients of the above indices range from 0 to 1, where values higher than 0.7 are accepted and lower values are evaluated as unfavorable. The fourth factor in evaluating the internal consistency reliability of the model is composite reliability (CR). The value of the composite reliability coefficient also ranges from 0 to 1, where values higher than 0.7 are accepted and values less than 0.6 are evaluated as unfavorable. The results of Cronbach's alpha, Dillon-Goldstein's rho index, and composite reliability are shown in Table 4.

As shown in the table, the results of Cronbach's alpha, Dillon-Goldstein's rho index, composite reliability, and Average Variance Extracted (AVE) for all variables are higher than 0.7 and acceptable.

***B) Discriminant validity in the measurement model***

The third criterion for assessing the fit of measurement models is discriminant validity, which compares the correlation of a construct with its own indicators versus its correlation with other constructs. Acceptable discriminant validity indicates that a construct in the model interacts more closely with its own indicators than with other constructs. Two methods are generally used to measure discriminant validity; in this study, the Fornell-Larcker criterion was employed.

Discriminant validity is considered acceptable when the square root of the AVE for each construct is greater than the shared variance between that construct and others (the square of the correlation coefficients between constructs) in the model. This is examined according to the Fornell-Larcker method (Table 5) using a matrix where the diagonal elements contain the square root of the AVE for each construct, and the off-diagonal elements represent the correlation coefficients between constructs.

According to the results in Table 5, the square root of the AVE for the latent variables (located on the main diagonal of the matrix) is greater than the correlation values between them (located in the cells below and to the left of the diagonal). Therefore, it can be stated that in the present study, the latent variables in the model interact more significantly with their own indicators than with other variables.

As shown in the figure, the coefficients for all paths, except for the path concerning the impact of green logistics management on sustainability performance, are greater than 1.96, indicating the statistical significance of these paths.

***Testing Research Hypotheses***

Following the assessment of the measurement model fit, the research hypotheses were tested and evaluated. The results of the hypothesis testing are presented in Table 6.

**Validation of Hypotheses**

***Relationship between logistics management and resilient green hospital performance***

As shown in the table, the path coefficient representing the effect of logistics management on resilient green hospital performance yields a test statistic (T-value) of 0.242, which is below the threshold of 1.96. Therefore, this relationship is not statistically significant at the 95% confidence level, and the corresponding hypothesis is rejected.

**Table 6.** Results of Hypothesis Testing

| | Original Sample (O) | Sample Mean (M) | Standard Deviation | T-Statistic | P-Value |
|---|---|---|---|---|---|
| Green Logistics Management -> Sustainability Performance | 0.032 | 0.021 | 0.131 | 0.242 | 0.809 |
| Green Logistics Management -> Circular Economy Practices | 0.693 | 0.686 | 0.099 | 7.009 | 0.000 |
| Circular Economy Practices -> Sustainability Performance | 0.778 | 0.787 | 0.124 | 6.277 | 0.000 |
| Green Logistics Management -> Circular Economy Practices -> Sustainability Performance | 0.539 | 0.544 | 0.129 | 4.192 | 0.000 |
| Supply Chain Traceability -> Circular Economy Practices | 0.271 | 0.277 | 0.098 | 2.763 | 0.006 |
| Supply Chain Traceability * Green Logistics Management -> Circular Economy Practices | 1.134 | 1.132 | 0.081 | 14.015 | 0.000 |

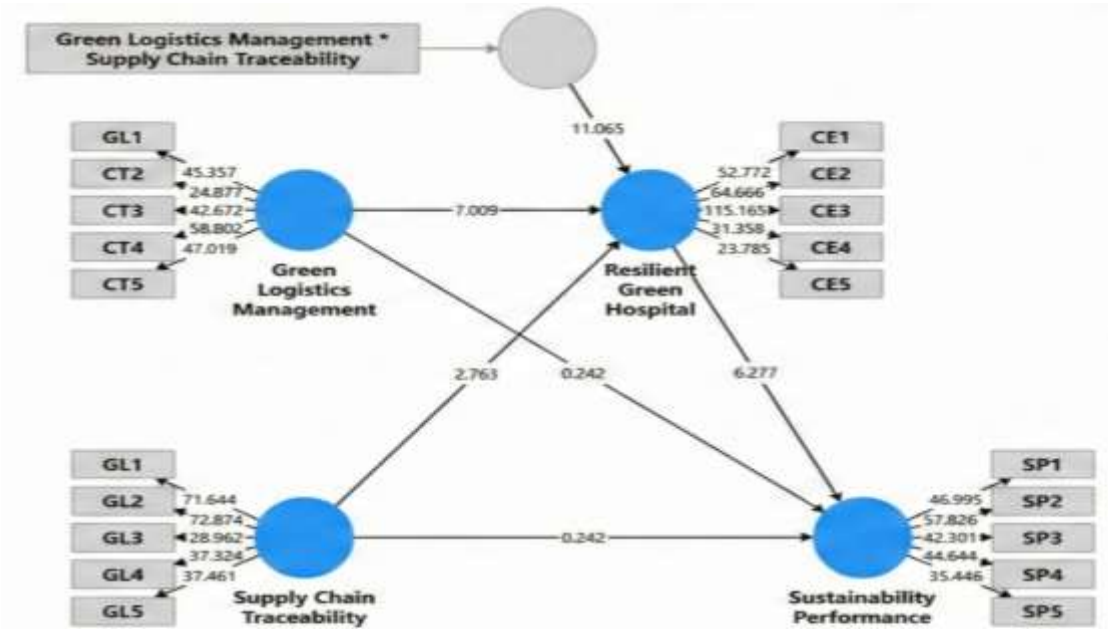


**Figure 2.** Z-significance coefficients (T-values)

***Impact of supply chain traceability on green hospital practices***

According to the table, the path assessing the impact of supply chain traceability on green hospital practices has a T-value of 7.009, exceeding the critical value of 1.96. This result indicates a statistically significant relationship at the 95% confidence level. Consequently, the second research hypothesis is accepted.

***Impact of green hospital practices on resilient green hospital performance***

The results indicate that the T-value for the path between green hospital practices and resilient green hospital performance is 6.277, which is greater than 1.96. This confirms a significant relationship at the 95% confidence level, leading to the acceptance of the third research hypothesis.

***Mediating role of green hospital practices between logistics management and resilient performance***

As reported in the table, the mediating effect of green hospital practices in the relationship between logistics management and resilient performance yields a T-value of 4.192, which exceeds the 1.96 threshold. This indicates a statistically significant mediating effect at the 95% confidence level. Accordingly, the fourth research hypothesis is accepted.

***Mediating role of green hospital practices in the relationship between supply chain traceability and resilient performance***

The results show that the mediating role of green hospital practices between supply chain traceability and resilient performance has a T-value of 2.763, which is greater than 1.96. This finding confirms a significant mediating relationship at the 95% confidence level. Therefore, the fifth research hypothesis is accepted.

### *Structural Model Fit Assessment*

The structural model was evaluated using Z-significance coefficients (T-values), where values greater than 1.96 indicate statistical significance at the 95% confidence level. Figure 2 presents the Z-significance coefficients (T-values) for the proposed research model.

## Discussion and Conclusion

This research aimed to develop a pharmaceutical supply chain traceability and logistics management model based on resilient green hospital performance during crises in Greater Tehran.

***Relationship between logistics management and resilient green hospital performance***

The results indicate that the significance coefficient (T-value) for this hypothesis is less than 1.96, suggesting that logistics management does not have a statistically significant effect on resilient green hospital performance. This finding contradicts prior studies by Cantobelli et al. (2018), Khan (2020), and Trivellas et al. (2020). Although previous research has shown that green logistics management enhances organizational sustainability performance, the findings of the present study suggest that, in the sampled organizations, green logistics activities—including transportation, warehousing, and waste management—did not contribute to improvements in operational or environmental sustainability performance. While green information management, reverse logistics, green transportation, efficient waste management, and sustainable monitoring and evaluation were found to reduce carbon emissions, waste, energy consumption, and resource use, these practices did not translate into measurable improvements in overall performance.

***Relationship between supply chain traceability and green hospital practices***

The significance coefficient (T-value) for this hypothesis exceeds 1.96, indicating a statistically significant relationship at the 95% confidence level. This result is consistent with the findings of Wang et al. (2020), and Kazancoglu et al. (2021). The findings confirm that supply chain traceability has a significant positive impact on green hospital practices. In this context, circular economy principles can be viewed as a contemporary approach that integrates economic, environmental, and social dimensions to enhance sustainability through improved resource utilization and stakeholder engagement.

***Mediating role of green hospital practices between logistics management and resilient performance***

The results show that the T-value for this hypothesis is greater than 1.96, confirming that green hospital practices significantly mediate the relationship between logistics management and resilient performance at the 95% confidence level. This finding aligns with previous studies by Wang et al. (2020) and Kazancoglu et al. (2021).

***Mediating effect of green hospital practices in the relationship between supply chain traceability and sustainability performance***

The T-value for this hypothesis exceeds 1.96, indicating a significant mediating effect at the 95% confidence level. This result is consistent with the findings of Wang et al. (2020).

***Moderating role of supply chain traceability in the relationship between logistics management and green hospital practices***

The results demonstrate that the T-value for this hypothesis is greater than 1.96, confirming a significant moderating effect of supply chain traceability at the 95% confidence level. Green hospital practices involve the adoption of environmentally friendly measures aimed at reducing energy consumption, emissions, and material waste throughout multi-stage production and logistics processes. Integrating these practices into logistics management can enhance system durability, maintenance efficiency, reuse, and refurbishment. However, factors such as increased costs, skill shortages, limited awareness, quality trade-offs, and supply chain complexity can hinder implementation. In this regard, supply chain traceability plays a critical role in overcoming these barriers by improving transparency, coordination, and control, thereby supporting the adoption of green practices and enhancing overall sustainable performance.

## Compliance with Ethical Guidelines

Ethical approval was not required for this study.

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This study was conducted without external funding.


## Author's Contributions

The author was solely responsible for the conception, design, data collection, analysis, and writing of this manuscript.

## Conflict of Interests

None.


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