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'Development and Psychometric Testing of the Lean Management Scale for Nursing Services in Hospitals'

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Keywords: instrument development | lean management | nursing | psychometrics

ABSTRACT

Aim: The aim of this study is to develop a new instrument (The Lean Management Scale for Nursing Services in Hospitals- LMS-N) to evaluate the lean levels of nursing services in hospitals and to evaluate its psychometric properties.

Method: A three-phase construct was used to develop this scale and to determine its psychometric properties: (1) creating the item pool, (2) preliminarily evaluating items and (3) evaluating psychometric properties. This methodological study evaluated the scale's face, content and construct validities, internal consistency, and temporal stability. The psychometric properties of the scale were tested with a total of 695 nurses in different sample groups. Data were collected between 18 November 2020 and 15 May 2021.

Results: The scale's content validity index was 0.75. According to principal component analysis, the scale included 22 items and five subdimensions, and the total variance was 60.32%. In confirmatory factor analysis, the fit indices were good or acceptable for this construct. Its internal consistency was good or acceptable according to reliability analysis. Test–retest showed that the scale had temporal stability.

Conclusion: Lean Management Scale in Nursing Services in Hospitals is a valid and reliable tool that can evaluate the level of leanness of nursing services. It provides a comprehensive evaluation with five subdimensions: management support, visual stock management, work environment layout, preventive notification system and waste detection.

SUMMARY STATEMENT

What is already known about this topic?

- Lean management is to support nurses in gaining more control over their duties, increasing work efficiency, and reducing waste.
- Using a valid and reliable measurement tool that includes the lean management concept is a critical step to improve non–value-added activities and irregular working conditions in nursing services and to increase the quality of service and care provided by nurses.

What does this paper add?

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- The Lean Management Scale for Nursing Services in Hospitals (LMS-N) is a valid and reliable tool that can be used for evaluating the level of lean of nursing services in hospitals.

The implications of this paper

- The LMS-N can be used to evaluate the leanness level of nursing services in hospitals.
- With the LMS-N, accurate and consistent data can be obtained to determine what leads to waste and non–value-added activities in nursing facilitating better management of nurses' working time.
- The data obtained with LMS-N can guide nurse managers in determining the strategies to be followed to make the necessary improvements that can ensure lean nursing services.

1 | Introduction

Lean management (LM) involves reducing non–value-added activities and diversity in processes, bettering poor working conditions and continuously advancing business processes with performance monitoring methods (Rotter et al. 2019). It advocates respect for people, continuous education, effective use of human talent and a lean organisational culture (Graban 2018; Ohno 2018). As such, LM is considered a valid and sustainable solution for higher healthcare costs and quality and productivity problems (Graban 2018; Knowles and Barnes 2013). With LM approaches, healthcare organisations or hospitals gain an advantage in providing healthcare at the right place and time (Barnas and Adams 2016; Graban 2018) and can effectively reduce healthcare delivery complexity and prevent waste (Barnas and Adams 2016; Graban 2018; Magalhães et al. 2016).

Lean management also positively affects nursing services as it aims to identify and eliminate waste, standardise and improve processes and thus optimise nurses' time (Graban 2018). In this context, some studies have shown that LM practices reduce medicine delivery times (Byrne 2018), result in fewer orders of needed materials and reduce excess stock (Toda and Ginj 2019), decrease the number of documents returned to the clinic pending evaluation (Yılmazlar 2015) and diminish patient waiting times and error rates (Aguilar-Escobar, Bourque, and Godino-Gallego 2015). In addition, with LM practices, nurses prioritise patient care (Van Rossum et al. 2016), have more control over and allocate more time to their basic tasks (Kieran et al. 2017; O'Mahony et al. 2021) and increase their work efficiency (Ayaad et al. 2019; Costa et al. 2017). Also, costs (Kotchevar 2015) and waste are reduced (Bryant and Yoder 2021). Besides patient care and safety are improved by eliminating non–value-adding activities with LM, order is provided in the units where nurses work and standardised, better and safer working environment are created (Kieran et al. 2017; Kavanagh and Donnelly 2020). The results of these mentioned studies were evaluated with semistructured questionnaires or measurement tools related to different subjects (e.g. stress levels) before and after LM practices. Also, there are a limited number of valid and reliable measurement tools in the literature on the measurement of LM practices. These are mostly tools designed for the industry (Machado Guimarães and Crespo de Carvalho 2014). The scales designed for healthcare organisations do not assess lean thinking in nursing services per se (Reponen et al. 2021) or are on lean leadership (Mulders 2016). In only one study, there was a scale that assesses a measure of leanness for general quality improvement processes in hospitals for nurses. This scale focuses more on quality management and comprises 79 items and 12 factors. It takes time to answer due to the large number of items and is, therefore, difficult to use in practice (Roszell and Lynn 2016).

It is important to use measurable data in determining and improving managerial elements (Sato et al. 2016). Although it is known that the quality of service and care provided in nursing services can increase with LM (Davies, Lyons, and Whyte 2019), the inability to measure the level of leanness of nursing activities or the working environment makes it difficult to show the relationship between LM and the results of nursing services (Roszell and Lynn 2016). However, data on the level of leanness should be based on the opinions of the employees of the organisation because an organisation is only as 'lean' as its employees perceive and obtaining the opinions of nurses on lean levels in hospitals is crucial (Jayamaha et al. 2014; Losonci, Demeter, and Jenei 2011). Therefore, valid and reliable measurement tools are needed to comprehensively evaluate the results of LM practices with the opinions of nurses in healthcare settings and nursing services and to measure lean management levels accurately and consistently.

2 | The Study

2.1 | Aim

This study aimed to develop a scale to evaluate nursing services' lean levels in hospitals and to test its psychometric properties.

2.2 | Methodology

This was a methodological study with a three-phase design: (1) creating the item pool, (2) preliminarily evaluating the items and (3) evaluating psychometric properties (Figure 1). The scale development guides and important roadmaps recommended by Carpenter (2018), DeVellis (2017), Boateng et al. (2018) and Seçer (2018) were taken as references in this scale development study.

2.2.1 | Phase 1. Creating the Item Pool

LM application examples from Bursa Medicabil Hospital Lean Health Institute, Wisconsin Theda Care, Washington Virginia Mason Medical Center, Michigan University Medical Center and Institute for Healthcare Improvement were analysed to

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PHASE 1

CREATING THE ITEM POOL

Literature Review: Research on lean management, lean hospitals concept, and other developed scales were examined (draft scale: 104 items)

PHASE 2

PRELIMINARY EVALUATION OF THE ITEMS

Face validity

- Opinions of 5 academic nurses regarding the language and understandability of the scale's items were obtained while creating scale items *(16 items were corrected for wording and punctuation errors and 2 items were edited for meaning).*

Expert opinion

- Opinions of 15 experts in Nursing Management were received with the Lawshe Technique. CVR and CVI were calculated (25 items removed).
- Opinions were also received from 15 experts regarding the face/language validity of the scale, simultaneously with content validity (12 items were edited for language and meaning.)
- Moreover, the opinions of 2 linguists were received *(15 items were edited for legibility and comprehensibility).*
- The draft scale was formed with 79 items.

Pilot Study

- The draft scale was applied face to face to 38 nurses and their opinions were received about the items *(3 items were improved only for clarity).*
- The Cronbach Alpha value of the draft scale was found to be 0.95.

PHASE 3

REFINING THE SCALE AND EVALUATING THE PSYCHOMETRIC PROPERTIES

Construct Validity

• **Principal component analysis (n:380)**	57 items with factor load <0.45 or were cross-loaded were deleted. The scale had 22 items and 5 sub-dimensions at this stage.
• **Confirmatory factor analysis (n:247)**	The fit indices were acceptable and good. Standardized factor loads were between 0.39 and 0.94. The scale created by EFA has been validated.
• **Reliability**	
• **Internal consistency (n:247)**	Cronbach Alpha for scale was 0.87 Cronbach Alpha for subdimensions' was between 0.65 and 0.88.
	Item-total correlation coefficients were between 0.37-0.77.
• **Temporal stability (n:30)**	Two applications were made 30 days apart. The intraclass correlation coefficient > 0.88

FINAL INSTRUMENT

The Lean Management Scale for Nurses Services in Hospitals with 22 items and 5 subdimensions

FIGURE 1 | Phases in the development of the lean management scale for nursing services in hospitals.

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create the item pool. Additionally, the researchers scanned the literature for the keywords 'LM', 'lean thinking', 'lean hospital' and 'nursing' (Ayaad et al. 2019; Barnas and Adams 2016; Bryant and Yoder 2021; Field-Richards 2017; Graban 2018; Liker and Convis 2017; Magalhães et al. 2016; Nicosia et al. 2018; Ohno 2018; Roszell and Lynn 2016; Rotter et al. 2019; Womack and Jones 2016) and created the scale items using the information from related studies and face-to-face meetings with the managers and clinical nurses in the hospitals.

The draft scale, Lean Management Scale for Nursing (LMS-N), included 104 items under six subdimension:management support (covers the management support that is essential for the implementation of lean management practices), visual stock management (covers the evaluation of systems that facilitate access to all materials/equipment needed), work environment layout (covers the evaluation of standardised sustainable work environment), preventive notification system (involves the evaluation of systems that will prevent errors before they occur), waste detection (evaluates the existence and causes of waste, which is an obstacle to LM for nurses) and activity management (evaluates value-adding activities in nursing activities). These subdimensions were determined by taking into account the basic elements of lean management, which are emphasised in Graban's (2018) 'Lean Hospital' concept and overlap in some critical publications (Barnas and Adams 2016; Graban 2018; Kotchevar 2015; Magalhães et al. 2016; Roszell and Lynn 2016; Womack and Jones 2016). The 5-point Likert-type draft scale is scored from 5-*strongly agree* to 1-*strongly disagree*.

2.2.2 | Phase 2: Preliminary Evaluating of the Items

2.2.2.1 | Face Validity. Opinions were received from five academic nurses with at least 5 years of nursing and academic experience. Academic nurses were asked to review the determined candidate items regarding their relationship with the concept, clarity and comprehensibility. Accordingly, 16 items were corrected for wording and punctuation errors, and two items were edited for meaning. Items were clearly written, avoiding double-negative and directive statements.

2.2.2.2 | Expert Opinion. Fifteen academicians (13 nursing management specialists and two LM specialists) evaluated the scope validity using the Lawshe technique. Content validity was examined by calculating each item's Item-Content Validity Index (I-CVI) and the Scale-Content Validity Index (S-CVI/average) for the total scale. Experts rated each item as 1 = required, 2 = useful but lacking and 3 = unnecessary (Lawshe 1975). To eliminate scoring bias among the experts, their statements were obtained by e-mail. As a result, 25 items with an I-CVI value of 0, negative (–) and below 0.49 at $\alpha = 0.05$ significance level were removed.

Additionally, expert opinion was taken for content validity and simultaneous language validity, and 12 items were revised for language and meaning. The scale was re-evaluated by two linguists. Fifteen items in the scale were revised for readability and intelligibility.

These steps gave a 79-item draft scale (53 positive, 26 negative).

2.2.2.3 | Pilot Study. The scale was pilot tested with 38 nurses to determine whether the draft scale items were understandable or answerable by a small group representative of the target group and edit them as necessary. The nurses were asked to identify any items that should be removed or added and offer suggestions for improvement (Seçer 2018). Accordingly, only three items were improved for intelligibility. The LMS-N was finalised with 79 items with a Cronbach alpha value of 0.95.

2.2.3 | Phase 3. Evaluating the Psychometric Properties

2.2.3.1 | Construct Validity. For construct validity, firstly, the skewness and kurtosis range (between −1 and 1 for both skewness and kurtosis) was evaluated for normally distributed items. Moreover, the presupposition tests for the applicability of the analysis, Kaiser–Meyer–Olkin (KMO), Barlett and anti-image correlation tests were performed. Construct validity was carried out with principal component analysis (PCA) and confirmatory factor analysis (CFA). In the study, PCA was preferred because it identifies key factors by simplifying complex data with minimal loss of information in a multivariate dataset and is a powerful statistical technique that maximally represents the main variance of the original dataset (Alavi et al. 2020; Shrestha 2021; Suhr 2005). In addition, Varimax rotation methods were used together with PCA, which is frequently used in scale development studies when a high correlation between factors is not expected or when it is thought that the emerging factors will be independent of each other (Acal, Aguilera, and Escabias 2020; Alavi et al. 2020; Çokluk, Şekercioğlu, and Büyüköztürk 2021; Field 2013). Also, it is argued that Varimax rotation is the best option as it redistributes the variance explained among all rotated components to facilitate PCA interpretation (Acal, Aguilera, and Escabias 2020). To obtain a more robust factor structure, items with cross-loading (loaded > 0.30 in two or more dimensions and difference between factor loadings < 0.1) (Celebi Cakiroglu and Baykal 2021; Kline 2019) or items with factor loads < 0.45 were eliminated (Alpar 2022) because, according to the literature, the lowest factor load value between 0.30 and 0.40 is acceptable, 0.50 and above has practical significance and 0.70 and above explains the structure well (Alpar 2022). The factor number of the scale was decided based on the scree plot and the eigenvalue > 1 criterion (Suhr 2005; Shrestha 2021).

CFA was performed to confirm the scale structure formed by PCA. The modification indices were evaluated to increase the model's power by adding covariance between the error terms. The convergent and discriminant validity of the scale was evaluated, and correlations between fit indices, standardised factor loads, average variance extracted (AVE), composite reliability (CR) and subdimension of the scale were reported for the final model.

2.2.3.2 | Reliability. After confirming the factor structure, the scale's internal consistency was evaluated using the item–total correlation and Cronbach's alpha coefficients. Temporal stability was evaluated with the test–retest method. The scale was applied twice with a 30-day interval on 30 nurses professionals with characteristics similar to those of the sample, and the intraclass correlation coefficient (ICC) was calculated.

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2.3 | Participants

Each phase of this study was carried out on different sample groups (Brahma 2009), with 695 nurses, including 15 experts in the item pooling phase, 38 nurses in the pilot study, 380 in the PCA phase, 247 in the CFA and reliability phase and 30 in the test–retest phase. An optimal sample size of at least 200 to 300 is recommended for scale development studies (Anthoine et al. 2014; Boateng et al. 2018). Comrey and Lee (2013) classify sample sizes as 50 (very poor), 100 (poor), 200 (fair), 300 (good), 500 (very good) and 1000 (excellent). It is also recommended that the sample size be at least 30 for the pilot test (Whitehead et al. 2016) and for the test–retest (Tavşancıl 2019). In this study, the sample size was appropriate for developing a scale with good psychometric properties. Convenience sampling, a nonprobability sampling, was used. The inclusion criteria were working as a nurse for at least six months in the said hospitals and volunteering to participate. A total of 730 surveys were distributed, and 712 nurses returned the surveys. Seventeen surveys containing missing information were not included in the analysis. The research was conducted with 695 participants.

2.4 | Data Collection

This study was conducted in three public hospitals and one university hospital affiliated with the Trabzon provincial health directorate. The pilot study and PCA were conducted at the university hospital and one public hospital and the CFA and retest at the other two public hospitals.

Firstly, Lawshe method opinions were obtained from 13 nursing management specialists and two LM specialist academicians from universities in Türkiye to create the item pool. Then, before collecting data to evaluate the draft scale items, the first researcher learned the number of nurses in the clinics from hospital managers, obtained the list of all units and visited each unit. After explaining the study's aim and content, nurses received the data collection instrument. Data collection tools were the draft LMS-N consisting of 79 items and the 10-question Nurse Information Form, which included participants' sociodemographic information such as age, gender, education and professional information such as worked years in a hospital and clinic. The first researcher visited the clinics at 4-day intervals to collect the data between 18 November 2020 and 15 May 2021. The response time of the data collection tool was 10–25 min for each participant.

2.5 | Data Analysis

Participants' characteristics and scale scores were determined by descriptive statistics (number, percentage, mean, standard deviation). The Lawshe Technique and Content Validity Index (CVI) were used for scale items' content validity. They were evaluated using the corrected item–total correlation coefficient. PCA with SPSS 20 and CFA with AMOS 24.0 software were performed for construct validity. The maximum likelihood estimation method was used for CFA. AVE, CR and subdimension correlations were calculated for the convergent and discriminant validity of the scale. Reliability analysis was done by Cronbach's alpha, item–total correlation tests and temporal stability of the scale using the retest method.

2.6 | Ethical Considerations

Approval was obtained from the scientific research ethics committee of a university hospital (Number: 24237859-262, Date 17/03/2021). Institutional permissions were obtained from the hospitals where the research was conducted. Participation in the study was voluntary. The purpose, content, scope and method of the study were explained to the nurses, and informed consent was obtained from all nurses who agreed to participate.

3 | Results

3.1 | General Characteristics of Participants

In the PCA sample, 89.2% of the nurses were women, 66.3% had a bachelor's degree, their average age was 34.77 ± 8.34 years and their professional experience was 13.66 ± 8.19 years. In the CFA sample, 85% of the nurses were women, 75.3% had a bachelor's degree, their average age was 39.05 ± 7.31 years and their professional experience was 16.98 ± 7.83 years. The socio-demographic and professional characteristics of nurses in each phase of the study are presented in Table 1 in detail.

3.2 | Content Validity

As a result of the content validity evaluation obtained with expert opinions, the I-CVI and the S-CVI of the draft LMS-N were 0.60–1.00 and 0.75, respectively.

3.3 | Construct Validity

In the PCA, the KMO value of the 79-item draft scale was 0.845, Bartlett's test result was $x^2 = 3197{,}385$, the p-value was $0.000 < 0.05$ and the anti-image correlation value was between 0.667 and 0.943. According to these results, the data had a multivariate normal distribution, and the sample size was adequate and appropriate for PCA. The rotation process with Varimax was applied seven times for PCA. A total of 57 items with a factor loading value of less than 0.50 and/or cross-loading were removed. Factor loading values for each item were between 0.542 and 0.889. The scree plot graph showed a straight line after the fifth main component (Figure 2). The draft scale was finalised with five subdimensions and 22 items. LMS-N's five subdimensions were 'management support, visual stock management, work environment layout, preventive notification system and waste detection' and explained 60.32% of the scale's total variance by 20.40%, 11.42%, 10.12%, 9.97% and 8.39%, respectively. The Cronbach alpha of the scale was 0.860. Details of the PCA are presented in Table 2.

CFA was performed to confirm the structure of the scale, which had five subdimensions and 22 items. The KMO value before CFA was 0.82, Barlett's test result was $X^2 = 2791.748$, the p-value was 0.000 and anti-image correlation was between 0.658 and

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TABLE 1 | Participants characteristics ($n = 695$).

Characteristics	Pilot study ($n = 38$) M ± SD or n (%)	Item reduction and PCA ($n = 380$) M ± SD or n (%)	CFA and internal consistency ($n = 537$) M ± SD or n (%)	Temporal stability ($n = 34$) M ± SD or n (%)
Age	35.26 ± 8.70	34.77 ± 8.34	39.05 ± 7.31	34.93 (7.94)
Sex				
Famele	33 (86.8)	339 (89.2)	210 (85.0)	26 (86.6)
Male	5 (13.2)	41 (10.8)	37 (15.0)	4 (13.4)
Marital status				
Single	14 (36.8)	121 (31.8)	63 (25.5)	23 (76.6)
Married	24 (63.2)	259 (68.2)	184 (74.5)	7 (23.4)
Education				
High school	7 (18.4)	41 (10.8)	13 (5.3)	2 (6.7)
Associate degree	2 (5.3)	56 (14.7)	42 (17.0)	3 (10.0)
Bachelor's degree	23 (60.5)	252 (66.3)	186 (75.3)	25 (83.3)
Graduate degree	6 (15.8)	31 (8.2)	6 (2.4)	0 (0)
Position				
Nurse	26 (68.4)	327 (86.1)	233 (94.3)	22 (73.3)
Manager Nurse	12 (31.6)	53 (13.9)	14 (5.7)	8 (26.7)
Professional experience	14.16 ± 8.86	13.66 ± 8.19	16.98 ± 7.83	14.41 (7.71)
Years of work in the hospital	13.03 ± 8.78	10.42 ± 7.56	11.94 ± 7.71	8.79 (6.76)
Years of work in the unit	9.79 ± 7.53	7.61 ± 6.14	6.82 ± 5.99	5.62 (4.51)
Satisfaction with organisation and functioning of the unit				
Yes	23 (60.5)	272 (71.6)	122 (49.4)	12 (40)
No	15 (39.5)	108 (28.4)	125(50.6)	18 (60)

Abbreviations: CFA, confirmatory factor analysis; PCA; Principal component analysis, exploratory factor analysis; M, mean; SD, standard deviation.

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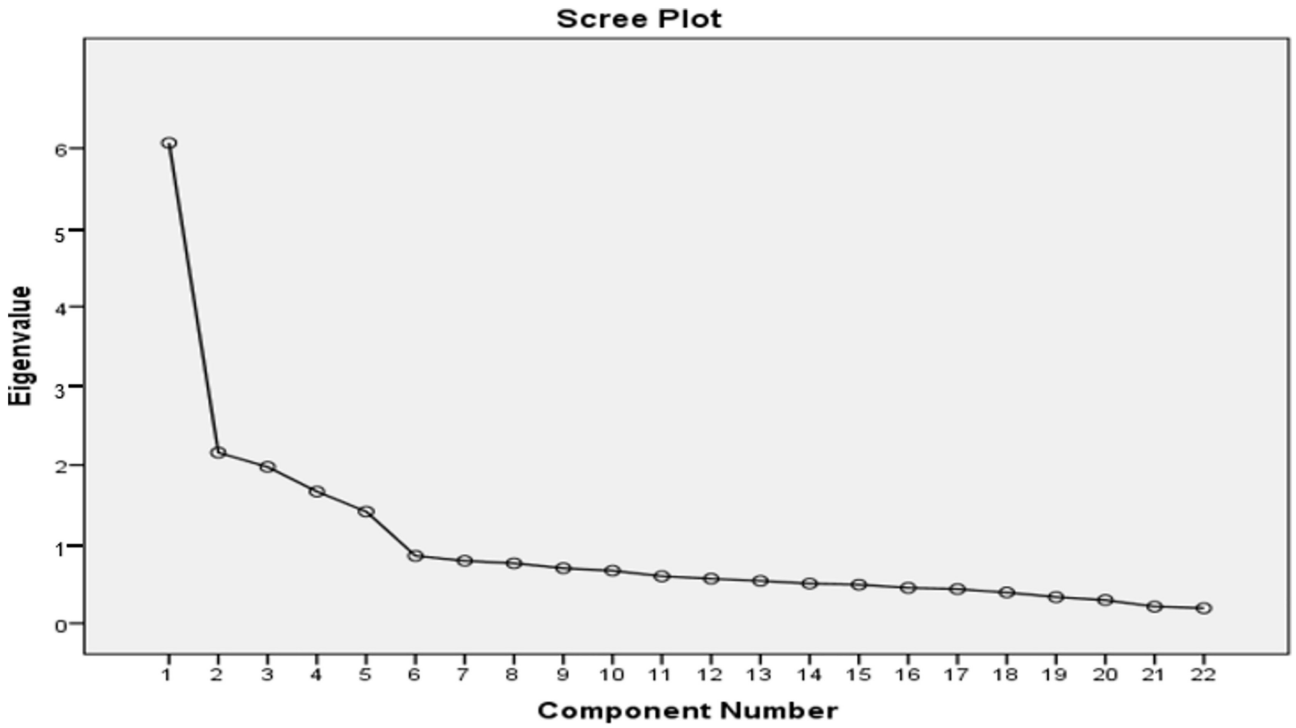


FIGURE 2 | Scree plot for exploratory factor analysis.

0.914. Modification indices were evaluated to improve model fit with CFA. A significant correlation was found between items 33 and 36, 77 and 72 and 57 and 72. The model was revised with three modifications by adding covariance links between the error term pairs of these items. As a result, the fit indices of the LMS-N improved: $\chi^2 = 408.045$, $p < 0.001$, $\chi^2/sd = 2.082$, GFI = 0.87, IFI = 0.92, TLI = 0.90, CFI = 0.92, RMSEA = 0.06 and RMR = 0.08. See detailed information in Table 3.

The convergent and discriminant validity of the scale was tested. Scale subdimensions had AVE values between 0.51 and 0.55 and CR values between 0.74 and 0.79. Standardised factor loads of all items were between 0.39 and 0.94 and were statistically significant. The scale total score and scores from each subdimension were correlated (Table 4).

3.4 | Reliability Analysis

For the scale's reliability, the total Cronbach alpha value was 0.87. The Cronbach alpha values of the subdimensions were between 0.65 and 0.88. No items caused an increase in Cronbach's alpha coefficient when deleted. Item–total correlation values were between 0.37 and 0.77 and were significant ($p < 0.001$) (Table 4). Additionally, Cronbach's alpha coefficients in the nurse group were 0.80 for total LMS-N and between 0.65 and 0.81 for the subdimensions. Cronbach's alpha coefficients in the nurse managers group were 0.90 for total LMS-N and between 0.60 and 0.89 for the subdimensions.

The retest performed to determine the temporal stability of the LMS-N yielded a statistically significant positive correlation between LMS-N pretest and posttest scores (r = 0.939; $p = 0.000$). The comparison of pretest and posttest scores showed no statistically significant difference between the mean scores ($t = 0.925$, $p = 0.363$). The scale's total ICC value was 0.96 (F = 31.59, $p < 0.001$, CI: 95%) (Table 5).

3.5 | Final and Scoring of the Scale

The LMS-N includes 22 items and five subdimensions, namely, Perceived Management Support (eight items), Visual Stock Management (four items), Work Environment Layout (four items), Preventive Notification System (three items) and Waste Detection (three items, need to be reverse scored). The 5-point Likert-type scale is scored from (l) *strongly disagree* to (5) *strongly agree* (Appendix 1). The scoring system depends on calculating the average scores. The average score for the LMS-N and its subdimensions ranges from 1 to 5. The scores indicate a low lean level if between 1.00 and 2.33), an average lean level if between 2.34 and 3.66 and a high lean level if between 3.67 and 5.00. Higher scores indicate higher lean levels.

4 | Discussion

For nurses, there is a need for valid and reliable measurement tools that can measure LM multidimensionally, have completed psychometric analyses and are easy to use in practice. However, an examination of the scales related to LM in the field of nursing revealed only the Lean Quality Improvement scale (Lean QI) developed by Roszell and Lynn (2016). This scale was examined with a small number of subjects and only with EFA. In addition, the scale has 12 dimensions, with some dimensions containing less than three items, and it takes approximately 20 min to complete due to its 75-item content. The scale with these limitations is not practical. In addition, the subdimensions focus on quality improvement rather

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TABLE 2 | Final principal component analysis of the lean management scale for nursing services in hospitals ($n = 380$).

		Primary factor loadings of the items								
Items	Factors	F1	F2	F3	F4	F5	Mean	SD	Cronbach's alpha	
	Management support						2.64	0.82	0.881	
73	Employees are supported for change and development.	0.835					2.66	1.11		Total LMS-N 0.860
70	Improvements are provided to address root causes of problems to prevent recurrence.	0.794					2.71	1.05		
74	Employees are supported in developing their careers.	0.783					2.74	1.13		
69	Problems reported to the management are resolved at the first time	0.699					2.33	1.02		
66	Respect for employees is a priority in the institution.	0.696					2.96	1.26		
72	Continuous training is provided on process improvement and problem-solving methods.	0.668					2.80	1.09		
77	Stand-up meetings are held daily in units to resolve problems.	0.650					2.56	1.08		
57	Tasks are carried out with sufficient employees following the standards.	0.568					2.39	1.18		
	Visual Stock Management						2.97	0.89	0.790	
35	There is a visual control system in the clinic that indicates when medications are running low.		0.889				2.76	1.20		
34	There is a visual control system in the clinic that indicates when consumables are running low.		0.880				2.88	1.14		
36	The places where materials/equipment are stored are standardised with coloured visuals.		0.680				2.98	1.13		
33	Clinics have an improved systematic storage/shelving system that facilitates access to materials/equipment.		0.542				3.27	1.10		
	Work Environment Layout						3.23	0.80	0.702	

(Continues)

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TABLE 2 | (Continued)

		Primary factor loadings of the items							
4	Working areas (such as counters, desks, and tables) and tools (such as computers and files) are designed to remain organised.			0.797			3.32	1.07	
3	All tools (such as connecting cables) are organised to be enclosed or embedded.			0.708			3.03	1.17	
5	Treatment carts and tables are designed to keep medications and supplies organised.			0.683			3.37	1.08	
7	Furniture, vehicles, and devices are easily moved.			0.664			3.20	1.07	
	Preventive Reporting System						2.64	0.77	0.797
52	Incident reporting systems are used effectively.				0.837		3.30	0.93	
53	Medication error reporting systems are used effectively.				0.833		3.37	0.94	
54	Improvement reports are shared with employees.				0.691		3.00	1.04	
	Waste Detection						2.64	0.77	0.618
59	There is a waste of time and effort due to nonstandard tasks in the clinic.					0.783	2.58	1.03	
60	There are unnecessary repetitive activities such as going to the nurse station or the storage					0.739	2.61	1.05	
61	Problems related to treatment and care are not resolved on the first attempt.					0.632	2.72	0.99	
	Eigenvalue	4.489	2.514	2.228	2.195	1.847			
	Explained variance (%)	20.402	11.429	10.127	9.977	8.397			
	Cumulative variance	20.402	31.831	41.958	51.935	60.332			

Note: The scale items were translated from Turkish to English for international publication.

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TABLE 3 | Model fit index of the lean management scale for nursing services in hospitals regarding confirmatory factor analysis.

Fit index	Referance value			
	Good	Acceptable	Premodifications values of LMSN	Final model of LMS-N
X^2/df	<3	$3 < X^2/sd < 5$	2.45	2.08
GFI	≥0.95	≥0.85	0.84	0.87
IFI	≥0.95	≥0.90	0.89	0.92
TLI	≥0.95	≥0.90	0.87	0.90
CFI	≥0.95	≥0.90	0.89	0.92
RMSEA (90% CI)	≤0.05	≤0.08	0.07 (0.06–0.08)	0.06 (0.05–0.07)
RMR	≤0.05	≤0.08	0.08	0.08
SRMR	≤0.05	≤0.08	0.07	0.07

Abbreviations: CFI, comparative fit ındex; CI, confidence ınterval; df, degrees of freedom; GFI, goodness of fit ındex; IFI, ıncremental fit ındex; RMR, root mean square residual; RMSEA, root mean square error analysis; SRMR, standardised root mean square; TLI, Turker–Lewis ındex; X^2, chi square.

than the lean concept. Therefore, an easy-to-use LMS-N scale that can measure the level of leanness of nursing services accurately, consistently and multidimensionally, whose psychometric analyses have been completed, has been developed.

4.1 | The LMS-N's Psychometric Properties

In this study, content validity calculated with the Lawshe technique, S-CVI > 0.67 (Alpar 2022) and I-CVR was above the acceptable upper limit (Polit and Beck 2021). These results suggest that LMS-N can adequately represent the structure it wants to measure. To ensure construct validity, PCA and CFA were performed in line with the recommendations of the literature for scale development studies (Çokluk, Şekercioğlu, and Büyüköztürk 2021). According to the KMO coefficient and Bartlett's test, it was found that the data had a multivariate normal distribution, the sample size was adequate and it was appropriate to conduct analysis (Alpar 2022). In addition, LMS-N anti-image correlation values (>0.50) showed that the scale items were suitable for PCA (DeVellis 2017). The total variance explained by the five-factor LMS-N was found to be within the range recommended in the literature for multidimensional scales (50%–60%) (Çokluk, Şekercioğlu, and Büyüköztürk 2021; Suhr 2005). The variance explained by each subdimension was between 8.39% and 20.40%, explaining at least 5% of the total variance, as stated in the literature (Seçer 2018). It showed that the factor loadings of the LMS-N items in the PCA were significant (items > 0.50), and the structure was well explained (items > 0.70) (Alpar 2022; Boateng et al. 2018; Çokluk, Şekercioğlu, and Büyüköztürk 2021). Besides, the Cronbach alpha value of the scale in the PCA sample was in the acceptable range, showing that this multidimensional scale had internal consistency (Bonett and Wright 2015; Suhr 2005). These results showed that the scale is suitable for determining the lean levels of nursing services.

The structure of LMS-N obtained by PCA was confirmed by CFA. In evaluating the validity of the model of the LMS-N structure formed by PCA, the model fit indices GFI (≥ 0.85); IFI, TLI, CFI (≥ 0.90); and RMSEA, RMR (≤ 0.08) showed acceptable fit and χ^2/df (< 3) values showed good fit (Kline 2019; Seçer 2018). To obtain these fit indices, care was taken to make three modifications one by one and to base them on a theoretical structure/logical basis (Çokluk, Şekercioğlu, and Büyüköztürk 2021). However, according to the literature, the standardised factor loads of the items in the LMS-N are in the acceptable range (min 0.30 -. 40) (Alpar 2022). The convergent and discriminant validity results of the LMS-N are also acceptable (DeVellis 2017; Hair et al. 2014).

Reliability analyses of the LMS-N after CFA were conducted using the item–total correlation coefficient, Cronbach's alpha internal consistency coefficient and the retest method (DeVellis 2017). The Cronbach alpha coefficient of > 0.70 for the LMS-N total and > 0.60 for the subdimensions show that the scale has sufficient reliability (Cohen and Swerdlik 2018). Item total correlation values for CFA were also above the acceptable value (> 0.30) in this study (Badenes-Ribera, Silver, and Pedroli 2020; DeVellis 2017). These results proved that the LMS-N was reliable, and its items were homogeneous and distinctive. Finally, the correlation coefficient > 0.70 in the results obtained with the retest analysis and the ICC results showed that the scale had an acceptable level of stability and was free from random errors that may arise from the application (Alpar 2022; Tavşancıl 2019). These results proved that the LMS-N is a valid and reliable measurement tool.

4.2 | Scale Contents

The LMS-N subdimensions scales were named management support, visual stock management, work environment layout, preventive notification system and waste detection. While creating the item pool, the five subdimensions of the LMS-N, designed as six dimensions after validity and reliability analyses, proved to be consistent with the subdimensions and item distribution in the initial design.

Subdimension 1-Management Support: This subdimension addresses the fact that LM requires change, and the support and leadership of the management is essential in the realisation of change. It includes important elements of LM such as focusing

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TABLE 4 | Validity and reliability analyses of the lean management scale for nursing services in hospitals ($n = 247$).

Factors and items	Factor loadings of CFA	LMS-N' correlations values						Mean	SD	AVE	CR	Item–total correlation	Cronbach's alpha
		F1	F2	F3	F4	F5	Total						
Management support		1.00					0.850**			0.55	0.76		0.882
Item 73	0.80							2.80	1.08			0.711	
Item 70	0.84							2.84	1.03			0.757	
Item 74	0.78							2.87	1.01			0.703	
Item 69	0.69							2.53	0.94			0.648	
Item 66	0.71							2.78	1.16			0.661	
Item 72	0.59							2.88	0.99			0.624	
Item 77	0.55							2.81	1.07			0.556	
Item 57	0.54							2.55	1.08			0.535	
Visual stock management		0.33**	1.00				0.636**			0.54	0.75		0.827
Item 35	0.94							3.30	1.01			0.738	
Item 34	0.93							3.40	1.01			0.764	
Item 36	0.62							3.46	0.92			0.667	
Item 33	0.39							3.47	0.98			0.463	
Work environment layout		0.48**	0.40**	1.00			0.753**			0.51	0.76		0.829
Item 4	0.88							3.27	1.03			0.735	
Item 3	0.49							2.63	1.14			0.491	
Item 5	0.94							3.27	0.99			0.779	
Item 7	0.68							3.04	1.09			0.653	
Preventive notification system		0.19**	0.21**	0.20**	1.00		0.391**			0.54	0.79		0.842
Item 52	0.89							3.44	0.82			0.765	
Item 53	0.83							3.47	0.83			0.725	
Item 54	0.70							3.34	0.86			0.637	
Waste detection		0.24*	0.13*	0.25**	−0.11	1.00	0.407**			0.51	0.74		0.656
Item 59	0.84							2.47	0.93			0.545	

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TABLE 4 | (Continued)

Factors and items	Factor loadings of CFA	LMS-N' correlations values						Mean	SD	AVE	CR	Item–total correlation	Cronbach's alpha
		F1	F2	F3	F4	F5	Total						
Item 60	0.59							2.56	1.01			0.485	
Item 61	0.46							2.72	0.91			0.379	
Total LMS-N													0.878

Abbreviations: AVE, average variance extracted; CR, composite reliability.
*<0.05;
**<0.01; Pearson correlation analysis.

TABLE 5 | Temporal stability of the lean management scale for nursing services in hospitals ($n = 30$).

Factors	*r*	First application M ± SD	Second application M ± SD	*t*	*p*	ICC	CI (95%) Lower bound	CI (95%) Upper bound	*F*-value	*p*-value
Management Support	0.94	2.34 ± 0.66	2.37 ± 0.61	−0.62	0.53	0.97	0.93	0.98	33.19	0.000
Visual Stock Management	0.98	3.35 ± 0.53	3.35 ± 0.52	−0.57	0.57	0.99	0.98	0.99	174.66	0.000
Work Environment Layout	0.83	3.01 ± 0.72	2.91 ± 0.67	1.36	0.18	0.91	0.81	0.95	11.08	0.000
Preventive Notification System	0.80	3.46 ± 0.75	3.30 ± 0.81	1.85	0.07	0.89	0.77	0.94	9.13	0.000
Waste Detection	0.80	2.73 ± 0.91	2.56 ± 0.75	1.67	0.10	0.88	0.75	0.94	8.57	0.000
Total LMS-N	0.93	2.96 ± 0.40	2.93 ± 0.41	0.92	0.36	0.96	0.93	0.98	31.59	0.000

Abbreviations: CI, confidence interval; ICC, intraclass corelation cofficient; M, mean; *r*: Pearson's correlation; SD, standart deviation; *t*: Bağımsız gruplarda *t*-testi.

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on problem-solving, providing continuous training/improvement and career opportunities and respect for employees that are important for increasing employee motivation and implementing lean practices quickly/easily (Barnas and Adams 2016; Graban 2018; Liker and Convis 2017; Ohno 2018). *Subdimension 2-Visual Stock Management:* It is about the presence of systematic visual and coloured control/storage systems that will facilitate nurses' access to the necessary medication/materials. *Subdimension 3-Work Environment Layout:* It includes a well-organised, minimised, clean, effective and standardised work area. As such, it is an indispensable part of LM. Visual stock management and work environment layout subdimentions are very important for making everything needed easily visible, sharing or communicating information, controlling the unnecessary time nurses spend on nonclinical tasks and saving excess stock and general costs (Barnas and Adams 2016; Davies, Lyons, and Whyte 2019; O'Mahony et al. 2021; Toda and Ginj 2019). In other words, these two subdimensions were included in the LMS-N because they contribute to providing a sustainable working environment and support the internalisation of processes by employees (Graban 2018). *Subdimension 4-Preventive Notification System:* It is about incident and medication error reporting systems, their practical use and the sharing of improvement reports. LM is rooted in the principle of 'zero error' and is based on the principle of proactivity (Womack and Jones 2016). According to LM, failures in preventive notification systems, communication-related problems in hospitals and nurses' constant focus on error solutions prevent them from using their time effectively and efficiently (Costa et al. 2017; Graban 2018). This subdimension was included in the LMS-N because it is necessary for the contribution of LM to quality management. *Subdimension 5-Waste Detection:* This subdimension evaluates the waste of time and effort in the clinic and the presence of unnecessary repetitive activities. Therefore, the importance of this dimension lies in the lean thinking system focussing on the concept of 'waste' (Ohno 2018; Womack and Jones 2016). Reducing waste in nursing services is one of the important aspects of LMS-N as it allows nurses to spend more time on patient care creates an environment that supports the quality of care (Roszell and Lynn 2016) and provides benefits in terms of work efficiency and cost (Bryant and Yoder 2021; Byrne 2018; Rotter et al. 2019).

4.3 | Study Limitations

The psychometric work for LMS-N was conducted with the opinions of nurses from a few public hospitals in a city in Türkiye, which was a study limitation. The psychometric properties of the LMS-N can be evaluated in an international context and different nations, as its generalizability to other parts of the world is limited. Besides, concurrent validity or criterion-related validity was not conducted in this study. The fact that the study was conducted during the COVID-19 pandemic should also be taken into consideration.

5 | Conclusion

The LMS-N developed within the scope of this research has a good level of reliability and validity. This scale consists of five subdimensions, including management support (eight items), visual stock management (four items), work environment layout (four items), preventive notification system (three items) and waste detection (three items), for a total of 22 items. With this scale, the lean level of nursing services can be determined and compared, and it can also shed light on identifying non–value-added activities. The validity and reliability of LMS-N in different healthcare organisations or different populations can be evaluated by conducting adaptation studies in different cultures. This scale can be retested on nurses in different healthcare organisations and populations.

Author Contributions

Ç.T.K. and H.Ö made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data were involved in drafting the manuscript or revising it critically for important intellectual content and have given the final approval of the version to be published. Each author should have participate sufficiently in the work to take public responsibility for appropriate portions of the content. Ç.T.K. and H.Ö agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Ethics Statement

Prior to data collection, ethics committee approval was obtained from Karadeniz Technical University Faculty of Medicine Scientific Research Ethics Committee on July 24, 2020 (no: 24237859-498).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Statistical

The authors checked this research to make sure it complied with the Journal of Advanced Nursing statistical guidelines. Statistics were checked by expert statistician Naci Murat (eistatistik.com) before submission. E-mail:nacimurats@gmail.com.

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Appendix 1

Table A1. Lean management scale in hospitals for nurses.

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Management support					
Employees are supported for change and development.					
Improvements are provided to address root causes of problems to prevent recurrence.					
Employees are supported in developing their careers.					
Problems reported to the management are resolved at the first time					
Respect for employees is a priority in the institution.					
Continuous training is provided on process improvement and problem-solving methods.					
Stand-up meetings are held daily in units to resolve problems.					
Tasks are carried out with sufficient employees following the standards.					
Visual stock management					
There is a visual control system in the clinic that indicates when medications are running low.					
There is a visual control system in the clinic that indicates when medical consumables are running low.					

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	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
The places where materials/equipment are stored are standardised with coloured visuals.					
Clinics have an improved systematic storage/shelving system that facilitates access to materials/equipment.					
Work environment layout					
Working areas (such as counters, desks, and tables) and tools (such as computers and files) are designed to remain organised.					
All tools (such as connecting cables) are organised to be enclosed or embedded.					
Treatment carts and tables are designed to keep medications and supplies organised.					
Furniture, vehicles, and devices are easily moved.					
Preventive reporting system					
Incident reporting systems are used effectively.					
Medication error reporting systems are used effectively.					
Improvement reports are shared with employees.					
Waste detection					
There is a waste of time and effort due to non-standard tasks in the clinic.					
There are unnecessary repetitive activities such as going to the nurse station or the storage.					
Problems related to treatment and care are not resolved on the first attempt.					

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