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A literature-based framework for interior finish performance requirement

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Abstract: This study proposes a literature-based performance requirements framework for interior finishes to support the operation of indoor service robots. Publications were analyzed through three stages: literature review and evidence extraction, concept integration and candidate indicator development, and linkage analysis and framework formulation. Evidence was classified into finish characteristics, robot responses, and application conditions. Similar concepts were integrated, and a logical linkage matrix connected the evidence to candidate indicators. The analysis yielded ten common concepts and six performance requirement indicators. The perception domain comprises surface reflection characteristics, signal transmission stability, visual distinctiveness, and geometric distinctiveness. The navigation domain comprises friction and traction stability and flatness and continuity. Assessment items encompass material surface properties and the geometry and condition of installed finish surfaces. Sensor configuration, lighting, observation conditions, wheel configuration, and movement conditions were identified as application conditions. The framework organizes findings from robotics research into architectural assessment items and clarifies the basis for deriving the indicators. In practice, it provides a basis for selecting interior finishes, assessing installed surfaces, and developing quantitative assessment methods. Further expert review and experiments are needed to establish measurement methods and assessment criteria.

Keywords: *Indoor service robot, Interior finishes, Robot perception and navigation, Robot-friendly buildings, Smart+Building.*

1. Introduction

As indoor service robots are introduced into buildings for a variety of roles, ensuring reliable movement and task execution has become an important challenge. These capabilities depend not only on onboard sensors and control algorithms but also on the conditions of the surfaces observed by sensors and the floors in contact with the wheels. Visual localization requires the extraction of sufficient environmental features and the establishment of correspondences between consecutive images, while wheel–floor contact and slip affect both movement and localization in wheeled robots [1, 2]. Creating built environments that support indoor service robot operation therefore requires consideration of the characteristics of interior finishes and installed finish surfaces alongside the technical capabilities of robots.

Interior finishes affect robot perception and navigation in different ways. Signal transmission and specular reflection from glass and mirrors can cause laser-based sensors to incorrectly measure the position of a finished surface or detect objects behind it [3, 4]. In visual localization, low-texture surfaces and corridors with few distinctive features can make it difficult to identify sufficient feature points, while floor friction and flatness affect wheel contact and movement. Because interior finishes are surfaces that robots observe and physically interact with, they need to be considered in terms of perception and navigation when introducing indoor service robots into buildings.

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Previous studies have separately addressed the detection of reflective surfaces and transparent obstacles [3, 4], wheel slip and odometry errors [2], improvements in indoor localization [5], and robot-assisted floor surface measurement [6]. However, differences in sensors, robot configurations, and experimental environments make it difficult to collectively apply these findings to final selection, assessment of installed conditions, and reviews conducted before robot deployment. In particular, environmental characteristics such as reflectance, texture, and surface profiles are often presented alongside robot responses such as distance measurement errors, insufficient feature points, and slip. Applying these findings therefore requires clarification of the role of each concept and the relationships among them.

Accordingly, this study reorganizes finish-related characteristics and their effects on robot perception and navigation, which were reported separately in previous studies, from the perspective of performance requirements for interior finishes. On this basis, it proposes a framework of performance requirements for interior finishes that considers the operation of indoor service robots. Evidence statements and keywords were extracted from relevant publications, and findings with similar meanings and underlying mechanisms were integrated into common concepts to develop candidate indicators. A logical linkage matrix was then used to examine the relationships among the literature evidence, the characteristics of finish materials and installed finish surfaces, sensing and navigation mechanisms, and candidate indicators. This process yielded six performance requirement indicators and their associated assessment items across the perception and navigation domains. In this study, the scope of interior finishes encompasses both the surface properties of the materials themselves and the geometry and condition of installed finish surfaces. Lighting, observation conditions, and robot configurations are treated as application conditions for interpreting the relationships between finish surface characteristics and robot responses. This approach clarifies the basis for deriving the indicators and their scope of application, providing a foundation for future finish selection, assessment of installed finish surfaces, and development of quantitative assessment methods.

2. Literature Review

Research on indoor service robot operation has primarily addressed sensor-based environmental perception and localization, wheel–floor contact, and movement errors. The optical properties and visual and geometric features of interior finish surfaces, together with the floor surface and geometry, shape the environments that robots observe and navigate. This section reviews previous studies across three domains and examines the need for research to establish performance requirements for interior finishes. Table 1 summarizes the publications analyzed and the main topics reviewed.

Table 1.
Summary of the Literature Review.

Code	Author(s) and Year	Main Topics Reviewed
O1	Kneip et al. [7]	Laser range sensor measurement characteristics under different surface colors, brightness levels, materials, and incidence angles
O2	Choe, et al. [8]	LiDAR performance under darkroom and rainfall conditions and the effects of target reflection characteristics
O3	Park and Jung [4]	Transparent obstacle detection using a laser range sensor
O4	Li, et al. [3]	Reflections in LiDAR observations and their plane-based detection and utilization
O5	Słomiany, et al. [9]	LiDAR-based material identification using reflection intensity profiles in relation to distance and incidence angle
L1	Chen, et al. [1]	Feature extraction and matching in visual SLAM and environmental limitations
L2	Ock, et al. [5]	ORB-SLAM improvements for accurate localization of indoor mobile robots
L3	Shi, et al. [10]	Loop closure detection and place recognition under challenging observation conditions
L4	Gomez-Ojeda et al. [11]	Visual SLAM combining point and line features in low-texture environments

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L5	Wang, et al. [12]	Visual SLAM using point and line features in low-texture indoor scenes
L6	Zhang et al. [13]	State estimation degeneracy caused by insufficient observational constraints and methods for addressing it
L7	Schichler, et al. [14]	Localization using thermal imaging, LiDAR, and GNSS, and sensor-specific observation conditions
L8	Qu, et al. [15]	Review of point-line feature integration for feature extraction, matching, and localization in visual SLAM
M1	Prakash and Elango [2]	Factors affecting wheel slip and odometry errors
M2	Borenstein and Feng [16]	Sources of odometry errors and measurement and correction of systematic errors
M3	Belyaev, et al. [17]	Wheel slip detection and movement correction on heterogeneous surfaces
M4	Wilson, et al. [6]	Floor surface profile measurement using a mobile robot and low-cost sensors
M5	Pearson, et al. [18]	Relative floor friction estimation using wheel slip and motor current measurements from a wheeled robot

Note: O: Optical sensing; L: Localization; M: mobility.

2.1. Optical Properties of Finish Surfaces and Distance Measurement

Studies examining the relationship between laser-based range sensors and the optical properties of finish surfaces have primarily investigated how surface reflection characteristics and observation conditions affect distance measurements. Kneip, et al. [7] analyzed the measurement characteristics of the Hokuyo URG-04LX under different surface colors, brightness levels, materials, and incidence angles, identifying measurement problems associated with low-reflectance and glossy surfaces Kneip, et al. [7]. Choe, et al. [8] evaluated LiDAR performance under rainfall and darkroom conditions and analyzed sensor responses in relation to target reflection characteristics and the observation environment Choe, et al. [8]. Słomiany, et al. [9] proposed a method for identifying material types, including transparent and reflective materials, using laser reflection intensity profiles characterized by distance and beam incidence angle [9]. These studies show that surface optical properties and observation conditions influence both distance measurements and the reflected signal information used for material identification.

Studies on transparent and reflective surfaces have addressed discrepancies between actual surface positions and sensor observations caused by signal transmission and specular reflection. Park and Jung [4] presented a method for detecting transparent obstacles using a laser range sensor [4], while Li, et al. [3] proposed a method for detecting reflections in LiDAR observations and incorporating them into localization and mapping using planar information [3]. By identifying uncertainties in distance measurements associated with transparent or highly reflective surfaces and proposing methods for their detection or correction, these studies demonstrate the close relationship between the reflection and transmission characteristics of finished surfaces and robot perception of the environment.

2.2. Visual and Geometric Features of Finish Surfaces and Localization

Studies on localization using visual features have primarily addressed methods for extracting sufficient environmental features and establishing reliable correspondences between consecutive images. Chen, et al. [1] comprehensively reviewed the main approaches to visual SLAM and their environmental limitations [1], while Ock, et al. [5]presented an improved ORB-SLAM method for accurate localization of indoor mobile robots Ock, et al. [5]. Shi, et al. [10] proposed a loop closure detection method for recognizing previously visited places under challenging observation conditions Shi, et al. [10]. Gomez-Ojeda, et al. [11] proposed PL-SLAM, which combines point and line features to address low texture and uneven feature distributions Gomez-Ojeda, et al. [11]. Wang, et al. [12] also presented a localization method that combines point and line features in low-texture indoor scenes Wang, et al. [12]. Qu, et al. [15] reviewed point- and line-feature-based visual SLAM systems, examining feature detection and matching, backend optimization, and loop closure detection [15].

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These studies indicate that texture, feature types, and feature distributions can affect the stability of visual localization.

Studies using geometric information and multiple sensors have examined methods for improving localization by combining structural information from the environment with sensor observations. Zhang, et al. [13] analyzed degeneracy in state estimation when observations provide insufficient constraints and presented methods for addressing this problem Zhang, et al. [13]. Li, et al. [3] used planar information to detect reflections and incorporate them into mapping [3], while Schichler, et al. [14] examined a localization method that combines thermal imaging, LiDAR, and GNSS observations [14]. These studies highlight the importance of obtaining not only visual surface features but also geometric information, such as edges and planes, as well as observations from multiple sensors for localization.

2.3. Floor Conditions, Navigation, and Movement Errors

Studies examining the relationship between floor conditions and robot navigation have primarily addressed wheel–floor contact, slip, and odometry errors. Prakash and Elango [2] reviewed factors affecting wheel slip and odometry errors [2], while Borenstein and Feng [16] classified the sources of odometry errors and described errors associated with wheel and drive system characteristics and external navigation conditions Borenstein and Feng [16]. Belyaev, et al. [17] analyzed the relationship between motor current and the slip coefficient of a robot moving across heterogeneous surfaces and proposed a method for correcting its movement based on this relationship Belyaev, et al. [17]. Pearson, et al. [18] proposed a method for estimating relative floor friction characteristics using wheel slip and motor current measurements from a wheeled robot and compared the results across different floor surfaces [18]. These studies indicate that floor surface conditions affect wheel contact and slip, potentially resulting in discrepancies between actual and estimated displacement, and that robot responses can provide information for comparing floor friction characteristics.

Studies on floor geometry and unevenness have addressed the effects of surface profiles and local irregularities on robot movement. Wilson, et al. [6] presented a method for measuring floor surface profiles using a mobile robot and low-cost sensors [6], while Borenstein and Feng [16]identified irregularities such as floor protrusions, cracks, and debris as factors contributing to odometry errors [16]. These studies indicate that, in addition to the surface properties of flooring materials, height variations and geometric discontinuities in installed floor surfaces can affect continuous robot movement and displacement estimation.

2.4. Limitations of Previous Studies and the Need for This Study

Previous studies have separately examined the relationships between the optical properties of finish surfaces and distance measurements, visual and geometric information and localization, and floor conditions and navigation and movement errors. These studies indicate that surface reflection and transmission characteristics, texture and geometric information, wheel–floor contact, and floor geometry can affect robot perception and navigation performance. However, most have focused on individual technical issues, such as sensor measurement characteristics, localization algorithms, slip and odometry errors, and surface measurements. Consequently, the environmental characteristics and robot responses reported across different studies have not been fully integrated into a consistent framework. Differences in the surfaces examined, sensor configurations, observation conditions, and navigation conditions also make it difficult to directly apply individual findings to the selection of interior finishes or the assessment of installed finish surfaces.

Creating built environments that support indoor service robot operation, therefore, requires an integrated examination of the characteristics of finish materials and installed finish surfaces, as well as the associated robot perception and navigation responses reported separately in previous studies. It is also necessary to systematically identify the mechanisms through which each characteristic relates to robot performance. In particular, both the surface properties of materials and the geometry and

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condition of installed finish surfaces need to be considered, while sensor and operating conditions should be distinguished as application conditions. This allows the findings to be reorganized into performance requirements that can be applied from an architectural perspective. Accordingly, this study analyzes the relationships between the evidence and concepts presented in previous studies to derive performance requirement indicators and associated assessment items for interior finishes, providing a foundation for future finish selection, assessment of installed conditions, and development of quantitative assessment methods.

3. Research Methodology

This study proposes a performance requirements framework by analyzing the characteristics of interior finishes and their effects on indoor service robot perception and navigation, as reported in the literature. The study was conducted in three stages: literature review and evidence extraction, concept integration and candidate indicator development, and linkage analysis and framework formulation (Figure 1).

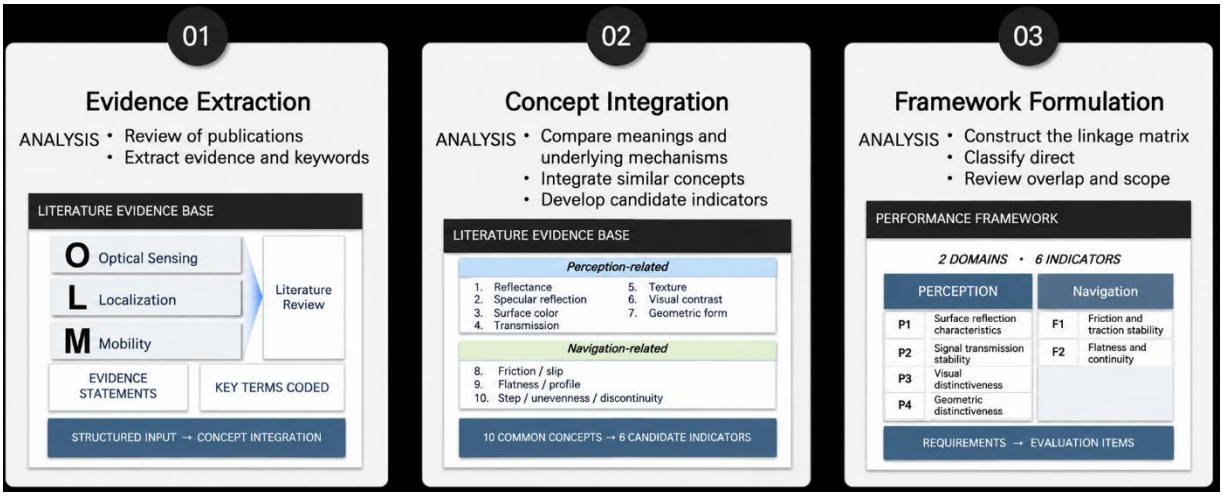


Figure 1.
Research process.

First, the publications included in the literature review were analyzed to examine how the characteristics of finish materials and finish surfaces affect sensor measurements, localization, and navigation. Individual phenomena or relationships and their associated statements were extracted as key units of analysis. The extracted information included the publication code, the location in the source text, evidence statements, and keywords.

Second, the extracted units and evidence statements were compared to integrate expressions with similar meanings into common concepts and develop candidate indicators. The analysis focused on the characteristics described by each expression. Expressions describing the same phenomenon were grouped into a single concept, while concepts involving different mechanisms were distinguished, including reflection and transmission, visual patterns and geometric forms, and friction and variations in floor height. During this process, robot responses such as distance measurement errors, insufficient feature points, and slip were distinguished from finish characteristics. Lighting, observation angle, robot load, and speed were identified as application conditions to consider when applying the indicators.

Third, a logical linkage matrix was constructed to connect literature evidence, the characteristics of finish materials and finish surfaces, sensing and navigation mechanisms, and candidate indicators. Relationships explicitly described in the source text between material, surface, or contact characteristics and robot perception or navigation were classified as direct linkages. Relationships established

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indirectly through descriptions of images, spatial information, or algorithms were classified as supporting linkages. The integrated concepts were then compared with the candidate indicators developed in the second stage to examine overlap and scope of application, and the final performance requirement indicators and associated assessment items were organized within the perception and navigation domains.

4. Derivation of Performance Requirement Indicators for Interior Finishes

4.1. Extraction of Literature Evidence and Organization of Concepts

Evidence statements and keywords describing the relationships between the characteristics of interior finishes and finish surfaces and robot perception and navigation were extracted from the 18 publications analyzed. The extracted information was classified into finish material characteristics and surface characteristics, robot responses, and application conditions. Reflectance, transmission, texture, and surface profiles were classified as finish surface characteristics, while distance measurement errors, insufficient feature points, limitations in point cloud registration, and slip were categorized as associated robot responses or problems in the perception process. Lighting, observation distance, incidence angle, robot load, speed, and wheel geometry were identified as application conditions affecting these relationships.

Evidence related to perception primarily concerned signal reflection and transmission and the formation of sensor observations. Reflection-related findings were organized into variations in signals received from surfaces, discrepancies in observed positions caused by specular reflection, and measurement differences associated with surface color and brightness. Transmission-related findings were grouped into signals passing through transparent surfaces, observations of objects behind them, and difficulties in identifying the boundaries of actual finish surfaces. Findings concerning visual and geometric information were organized into texture and feature distributions, visual distinctiveness relative to surrounding areas, and geometric information such as edges and planes.

Evidence related to navigation primarily concerned wheel–floor contact conditions and variations in floor geometry. Contact-related findings were organized into friction and slip under different surface conditions and discrepancies between actual and estimated displacement. Geometry-related findings were grouped into surface profiles representing floor height distributions and local irregularities such as protrusions and cracks. This organization allowed both the surface properties of finish materials and the condition of installed finish surfaces to be examined. Table 2 summarizes the main evidence and associated concepts for each publication.

Table 2.
Summary of Linkages between Literature Evidence and Concepts

Code	Evidence Summary	Associated Concepts
O1	Analysis of laser distance measurement characteristics under different surface colors, brightness levels, materials, and incidence angles	Reflection characteristics, surface color and brightness
O2	Evaluation of LiDAR performance in relation to target reflection characteristics and rainfall and darkroom conditions	Reflection characteristics, observation conditions
O3	Transparent obstacle detection using a laser range sensor	Transmission and reflection, boundary identification
O4	Detection of LiDAR reflections and their utilization with planar information	Specular reflection, transmission-related observations, planar structure
O5	Material identification using LiDAR reflection intensity profiles characterized by distance and incidence angle	Reflection characteristics, observation conditions
L1	Review of the roles of feature extraction and matching in visual SLAM and environmental limitations	Texture, visual features
L2	ORB-SLAM improvements for indoor mobile robot localization	Feature extraction and matching
L3	Loop closure detection for place recognition under challenging observation conditions	Visual distinctiveness
L4	Integration of point and line features to address low texture	Texture, feature distribution

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	and uneven feature distributions	
L5	Localization using point and line features in low-texture indoor scenes	Texture, line and structural features
L6	Analysis of state estimation degeneracy caused by insufficient observational constraints	Geometric constraints, observation information
L7	Localization combining thermal imaging, LiDAR, and GNSS observations	Sensor-specific feature information, spatial information
L8	Review of point–line feature integration for feature detection, matching, optimization, and loop closure in visual SLAM	Visual features, line and structural features
M1	Review of factors affecting wheel slip and odometry errors	Friction and slip, floor surface conditions
M2	Description of factors contributing to odometry errors, including floor irregularities and wheel slip	Slip, local unevenness
M3	Analysis of the relationship between motor current and slip on heterogeneous surfaces and correction of robot movement	Contact conditions, slip
M4	Floor surface profile measurement using a mobile robot and low-cost sensors	Surface observation characteristics, flatness and surface profiles
M5	Relative floor friction estimation using wheel slip and motor current measurements across different floor surfaces	Friction and slip, wheel–floor contact

Note: O: Optical sensing; L: Localization; M: Mobility.

4.2. Concept Integration and Candidate Indicator Development

The extracted keywords and evidence statements were compared to integrate findings with similar meanings and underlying mechanisms into common concepts. Integration was based on the finished-surface characteristics described by each expression and the mechanisms through which they affect robots. Expressions describing the same characteristic were grouped into a single concept, while those describing different mechanisms were distinguished. This process yielded ten concepts: reflectance; specular reflection; surface color and brightness; transmission and refraction; texture; visual contrast and tonal variation; geometric form and structure; friction and slip; flatness and surface profiles; and steps, surface irregularities, and unevenness. Table 3 presents the linkages between the integrated concepts and candidate indicators.

Table 3.
Linkages between Integrated Concepts and Candidate Indicators.

Integrated Concept	Conceptual Scope	Candidate Indicators
Reflectance	Ratio of the signal reflected from a surface to the incident signal	P1 Surface reflection characteristics
Specular reflection	Reflection in a specific direction depending on the incidence and observation directions	P1 Surface reflection characteristics
Surface color and brightness	Observation characteristics related to surface color and brightness	P1 Surface reflection characteristics
Transmission and refraction	Signals passing through finished surfaces and changes in their propagation paths	P2 Signal transmission stability
Texture	Surface patterns that form image features	P3 Visual distinctiveness
Visual contrast and tonal variation	Differences in color and brightness within a surface or relative to surrounding areas	P3 Visual distinctiveness
Geometric form and structure	Edges, planes, shapes, and spatial arrangements of finished surfaces	P4 Geometric distinctiveness
Friction and slip	Characteristics related to wheel–floor contact and relative slipping	F1 Friction and traction stability
Flatness and surface profiles	Height distribution and geometry of a floor surface over a given section	F2 Flatness and continuity
Steps, surface irregularities, and unevenness	Local height differences and discontinuities in floor surfaces	F2 Flatness and continuity

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Reflectance, specular reflection, and surface color and brightness were integrated into "surface reflection characteristics" because they relate to signals reflected from finish surfaces and the resulting observations. Reflectance describes the proportion of the incident signal that is reflected, specular reflection describes directional reflection characteristics, and surface color and brightness describe differences in observations associated with surface color and brightness. Transmission and refraction were classified under "signal transmission stability" because they concern signals passing through finish surfaces or changing direction. This distinction separates characteristics related to reflected signals from those related to identifying the boundaries of transparent surfaces.

Texture, visual contrast, and tonal variation were integrated into "visual distinctiveness" because they provide information used to extract features from images and distinguish surfaces from surrounding areas. Geometric form and structure were organized under "geometric distinctiveness" because the edges, planes, and spatial arrangement of finish surfaces provide spatial information. The two indicators were distinguished according to whether the information derives from surface patterns and brightness differences or from physical geometry and spatial arrangement.

Friction and slip were organized under "friction and traction stability" because they describe wheel–floor contact and the associated movement. Flatness and surface profiles, together with steps, surface irregularities, and unevenness, were integrated into "flatness and continuity" because they describe height variations and connections within floor surfaces. The former addresses surface conditions that support movement through contact, while the latter addresses the geometry of the floor surfaces traversed by the wheels. This concept integration yielded four candidate indicators in the perception domain and two in the navigation domain.

4.3. Linkage Matrix and Performance Requirements Framework

A logical linkage matrix was constructed to connect literature evidence, the characteristics of finish materials and finish surfaces, sensing and navigation mechanisms, and candidate indicators, thereby clarifying the basis for developing the indicators. Cases in which the literature explicitly addressed the relationship between surface or contact conditions and robot responses were classified as direct evidence (D), while those linked through mechanisms involving sensor observations and localization were classified as supporting evidence (B). Each linkage was established based on individual evidence statements. When a publication described different relationships, it was linked to multiple indicators. Table 4 presents the linkages between the publications and candidate indicators.

Table 4.
Logical Linkage Matrix.

Code	P1	P2	P3	P4	F1	F2
O1	D	–	–	–	–	–
O2	D	–	–	–	–	–
O3	D	D	–	–	–	–
O4	D	D	–	B	–	–
O5	D	-	-	-	-	-
L1	–	–	B	B	–	–
L2	–	–	B	–	–	–
L3	–	–	B	–	–	–
L4	–	–	B	–	–	–
L5	–	–	B	B	–	–
L6	–	–	B	B	–	–
L7	–	–	B	B	–	–
L8	-	-	B	B	-	-
M1	–	–	–	–	D	B
M2	–	–	–	–	D	D
M3	–	–	–	–	D	–
M4	D	–	–	–	–	D
M5	-	-	-	-	D	-

Note: D: Direct evidence; B: Supporting evidence; –: No Linkage identified in this analysis.

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In the perception domain, the relationships among indicators were organized according to how finish surfaces provide information to sensors. Surface reflection characteristics and signal transmission stability address optical interactions between sensor signals and finish surfaces, while visual distinctiveness and geometric distinctiveness address environmental information used for localization and spatial perception. This structure allows the acquisition of sensor observations and the use of the resulting information to be examined separately, even for the same finish surface.

In the navigation domain, wheel–floor contact conditions were distinguished from the geometry of the surfaces traversed by the wheels. Friction and traction stability address surface characteristics associated with contact conditions and slip, while flatness and continuity address floor height distributions and local discontinuities. Installed floors involve both the properties of the materials themselves and the connections at joints and transitions between materials. These connections were therefore included within the scope of flatness and continuity. Horizontal gaps and vertical level differences at joints were treated as distinct geometric conditions.

Based on these linkages, six performance requirement indicators were proposed: surface reflection characteristics, signal transmission stability, visual distinctiveness, and geometric distinctiveness in the perception domain, and friction and traction stability, and flatness and continuity in the navigation domain. The performance requirement indicators represent the characteristics that finish materials and finish surfaces need to provide for robot operation, while the associated assessment items specify the aspects to be examined. Table 5 presents the definitions and associated assessment items for each indicator.

Table 5.
Definitions and Assessment Items for Interior Finish Performance Indicators.

Domain	Code	Performance Requirement Indicator	Definition	Assessment Items
Perception	P1	Surface reflection characteristics	Characteristics involved in observing surface position and geometry through signals reflected from finish surfaces	Reflectance, specular reflection characteristics, surface color and brightness
	P2	Signal transmission stability	Characteristics enabling consistent identification of actual boundaries in relation to signal transmission and refraction through transparent or translucent finish surfaces	Transmission and refraction characteristics
	P3	Visual distinctiveness	Characteristics providing the visual information needed to extract and match image features and distinguish surfaces from surrounding areas	Texture, visual contrast and tonal variation
	P4	Geometric distinctiveness	Characteristics through which finish surface geometry and spatial arrangement provide geometric information required for localization and spatial perception	Geometric form and structure
Navigation	F1	Friction and traction stability	Characteristics supporting stable movement by maintaining wheel–floor contact and limiting slip	Friction and slip characteristics
	F2	Flatness and continuity	Characteristics through which floor height distributions and connections between surfaces support continuous wheel movement	Flatness and surface profiles; steps, surface irregularities, and unevenness

The proposed framework links robot perception and navigation problems reported in the literature to aspects of finish materials and finish surfaces that require assessment. At the finish selection stage, it supports examination of surface optical properties, visual information, and contact characteristics with wheels. For installed finish surfaces, it also addresses physical geometry and spatial arrangement, floor flatness, and connections between surfaces. Sensor type, lighting, observation distance and incidence

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angle, wheel configuration, and movement conditions are specified as application conditions, allowing finish surface characteristics and robot responses to be interpreted together.

The proposed performance requirements framework thus distinguishes the surface properties of finish materials from the geometry and condition of installed finish surfaces while linking both to robot perception and navigation processes. In the perception domain, optical interactions between sensors and surfaces, such as reflection and transmission, are distinguished from the provision of visual and geometric information. In the navigation domain, wheel–floor contact characteristics are distinguished from floor geometry and continuity. This structure allows different assessment items to be applied to the same finish material depending on its properties, installed condition, and robot operating conditions, providing a basis for establishing measurement methods and assessment criteria for each indicator.

5. Discussion

The performance requirements framework proposed in this study highlights the need to assess interior finishes by considering both their material properties and robot responses during perception and movement across finish surfaces. By distinguishing finish surface characteristics from robot responses and establishing their relationships, the framework separates environmental characteristics to be examined during design and construction from performance changes observed during robot operation. It can serve as a basic assessment structure for selecting interior finishes and examining the condition of installed finish surfaces from the perspective of robot operation.

In the perception domain, both how finish surfaces interact with sensor signals and how they provide information required for localization need to be considered. Even when a surface position can be observed, distinctive features or spatial constraints may be insufficient. Reflection and transmission characteristics and visual and geometric features therefore constitute complementary assessment items. Visual and geometric distinctiveness should also be considered together, as the availability of different types of features can support localization when one type of information is limited. In the navigation domain, wheel contact conditions and floor geometry likewise involve different mechanisms. Assessment should therefore consider not only the type of finish material but also its installed condition, including surface treatment, geometry, spatial arrangement, and joints.

Developing the proposed indicators into assessment methods requires linking finish surface characteristics to robot responses under specified application conditions. Responses to the same finish surface may vary with sensor type, lighting, observation distance and angle, wheel configuration, and movement speed. Specifying these conditions and comparing responses associated with the assessment items, such as distance measurement errors, localization stability, and slip, can help define the measurement methods and scope of application for each indicator. Robot responses may also provide a basis for comparing finish surfaces under consistent conditions. Such comparisons should be interpreted in relation to the sensor and wheel configurations and operating conditions used in the assessment. Surface characteristics shared by multiple indicators also need to be examined to avoid double counting during assessment.

As this study synthesizes findings from 18 selected publications, the scope of the literature and the researchers' interpretations may influence the indicator structure. Applying the literature-based conceptual linkages to practical assessment requires confirmation of the measurability and field applicability of each item. Future research should use expert review to examine the definitions of the indicators and the appropriateness of their associated assessment items, and conduct experiments on representative finish surfaces to specify assessment procedures under different application conditions.

6. Conclusion

This study proposed a performance requirements framework for interior finishes that considers indoor service robot operation. Evidence describing the relationships between the characteristics of finish materials and finish surfaces and robot perception and navigation was extracted from 18 relevant publications. Performance requirement indicators and associated assessment items were developed

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through the integration of similar concepts and analysis of their logical linkages. The main findings are as follows:

First, the extracted information was classified into finish materials and surface characteristics, robot responses, and application conditions. This classification linked environmental characteristics, such as reflectance, texture, and surface profiles, to robot responses, including distance measurement errors, difficulties in feature matching, and slip. Sensor and operating conditions influencing these relationships were also identified.

Second, the extracted concepts were integrated according to their meanings and underlying mechanisms, yielding ten common concepts and six performance requirement indicators. The perception domain comprises surface reflection characteristics, signal transmission stability, visual distinctiveness, and geometric distinctiveness. The navigation domain comprises friction and traction stability, and flatness and continuity. Each indicator was defined to encompass both the surface properties of finish materials and the geometry and condition of installed finish surfaces.

Third, the relationships between literature evidence and performance requirement indicators were presented in a logical linkage matrix, and associated assessment items were specified for examining each indicator. This organized the environmental characteristics and robot interaction mechanisms addressed in individual publications into a structure that can support finish selection and assessment of finish surfaces.

The contribution of this study lies in reorganizing evidence from the literature on robot perception and navigation into aspects for architectural assessment and making the derivation process and definitions of the performance requirement indicators explicit. The proposed framework can serve as a basis for selecting interior finishes and assessing installed conditions when planning robot deployment. Future research should examine the applicability of the indicators through expert review and experiments under different finish surface conditions and further specify measurement methods and assessment criteria.

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Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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