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Production Challenges in the Transition from S-57 to S-101

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ABSTRACT: This paper examines the transition from S-57 to S-101 in the context of implementing the S-100 framework, with particular attention to dual-fuel ENC production and its broader operational implications. The study is based on a comparative analysis of IHO normative documents, technical guidance on S-57-to-S-101 conversion, regulatory materials governing ECDIS use, and research literature on transitional production architectures. The analysis identifies the principal structural and functional differences between S-57 and S-101, including changes in data modelling, feature specification, portrayal logic, exchange mechanisms, validation procedures, data protection, and interoperability with other S-100 products. It shows that S-57→S-101 conversion cannot be understood as a simple format transformation, since it is constrained by semantic mismatches, differing relationship models, the need to normalize source data, non-equivalent update mechanisms, and the necessity of post-conversion validation and human review. The paper argues that dual-fuel production should be treated as a distinct production and implementation problem affecting database design, workflow organization, quality control, and transition planning. At the same time, the study emphasizes that these producer-side changes are not isolated from practice, since the shift toward the S-100 environment also has implications for ECDIS familiarization, training requirements, bridge procedures, and the broader conditions of navigational safety. The findings suggest that product-neutral database architectures provide the most sustainable long-term basis for parallel S-57 and S-101 production, although their adoption requires substantial institutional and technical investment.

1 INTRODUCTION

Modern digital technologies are assuming an increasingly important place in shipping, changing approaches to ship design, management, and operation. A typical example of such a technology is ECDIS, which reduces the adverse influence of the human factor and ensures that routine navigational operations are performed at a higher qualitative level. The electronic navigational chart is a key navigational tool within ECDIS, and the system itself has effectively replaced paper charts as the primary means of navigation and integrated other sources of navigational information into a single information environment.

At present, numerous studies are devoted to assessing and improving the effectiveness of ECDIS use, identifying the advantages and limitations of ENCs, enhancing training with electronic charts, and addressing problems related to the use and further development of ECDIS technologies for the improvement of navigational safety.

Typically, deficiencies in ECDIS use arise from human negligence, overconfidence, and, in some cases, insufficient competence. Common problems include excessive reliance on automation, information overload on the display, incorrect settings, fatigue, and related human factors. These issues can be mitigated only through a high level of competence and a thorough knowledge of ECDIS capabilities [1], [2].

While the operational use of ECDIS forms part of the competence requirements established by the STCW Convention, the additional preparation expected after assignment to a ship is regulated primarily through company responsibilities for familiarization and training. Regulation I/14 of the STCW Convention requires that seafarers be familiarized with their specific duties and with ship arrangements, installations, equipment, procedures, and characteristics relevant to those duties, while sections 6.3 and 6.5 of the ISM Code require proper familiarization and procedures for identifying and providing training in support of the safety management system. As a result, the regulatory framework does not establish a single uniform model for ECDIS-related onboard familiarization, which leaves room for different company practices, manufacturer materials, and course formats [3]-[5].

Although the need for additional ECDIS preparation is widely recognized, its practical delivery remains uneven. The combination of generic competence requirements, company-level familiarization obligations, and manufacturer-specific interface differences means that officers may satisfy the formal competence standard while still requiring system-specific familiarization with the equipment actually fitted on board. Differences among manufacturers, variations in flag-state expectations, and the absence of a fully uniform approach to such familiarization create uneven conditions of preparation and may adversely affect navigational safety.

Additionally, the introduction of the new S-100 standards framework from 1 January 2026 has brought producer-side issues of creating, converting, validating, protecting, and distributing marine cartographic data to the forefront of current implementation research. The S-100 framework, based on the ISO 19100 series [6], forms a multi-product environment within which S-101 coexists with S-102, S-104, S-111, S-124, S-128, S-129, S-131, S-164, and other product specifications. Under these conditions, S-98 becomes central, as it defines the rules of interoperability, joint portrayal, prioritization, and conflict management for multiple S-100 products in the S-100 ECDIS environment. Therefore, the transition from S-57 to S-101 should be regarded not as a simple update of the ENC format, but as a restructuring of the data model, portrayal rules, quality-control procedures, and production architecture. Particular importance is attached to the transition period during which hydrographic offices and publishers of electronic navigational charts must simultaneously support S-57 and S-101 products.

However, the regulatory and operational dimension of the problem does not disappear. Although the operational use of ECDIS is directly linked to competencies under the STCW Convention, Table A-II/1, the concrete organization of onboard familiarization, equipment-specific instruction, and competence maintenance largely remains within the company's area of responsibility in accordance with Regulation I/14 of the STCW Convention and the provisions of the ISM Code. Consequently, even purely producer-side changes within the S-100 framework will inevitably have implications for training procedures, bridge practices, the allocation of responsibility, and shipboard safety management arrangements [3]-[5].

2 PREVIOUS RESEARCH ANALYSIS

The literature on S-100 has clearly evolved from conceptual works on replacing S-57 to studies of applied implementation. Whereas earlier articles substantiated the very need for a universal hydrographic model, studies from 2022–2026 already focus on product specifications, portrayal, interoperability, user interaction, weather routing, the expansion of data domains, and cybersecurity.

Semantic and software compatibility has received the greatest attention in the literature. It is also in this area that the widest range of concrete problems has been identified, including overlap between product specifications, different ways of modelling similar entities, duplication of features, symbol conflicts, and difficulties in the simultaneous portrayal of different S-100-based products. Taken together, these works show that the principal challenge of S-100 is not simply to "create a new standard," but to make the various parts of this ecosystem genuinely coherent with one another [7].

Empirical studies of the human factor and operational use still present a generally positive, though not definitive, picture. The eye-tracking experiment reported in [8], conducted with deck officers who had more than three years of seagoing experience and held second-class licenses, indicates that S-100 ECDIS can accelerate voyage planning and reduce the visual effort required for search. Weather-routing research demonstrates the real potential of integrating S-101, S-111, and weather products to optimize ETA. At the same time, however, survey-based studies record risks: overreliance on electronics, loss of traditional navigation skills, difficulties in personnel adaptation, and the need to update training programs. Thus, the benefits of S-100 are already discernible, but they do not eliminate human-factor problems.

Finally, another relevant topic in this context is cybersecurity. While interoperability and portrayal problems are already actively discussed, the security dimension is only beginning to enter the research field. The 2026 article effectively shows that S-100 may contain design-level vulnerabilities, which means that, in the future, the certification of S-100-compliant systems should evaluate not only functionality but also security architecture [9].

Resolving problems related to the development, use, and improvement of ECDIS technologies remains a relevant scientific direction directly linked to the enhancement of navigational safety. Against this background, the present study focuses on IHO requirements and standards governing the creation, exchange, portrayal, and use of cartographic data in the context of the transition to S-100. The aim of the study is to identify and systematize the key differences between S-57 and S-101 in structural and functional terms, to determine the constraints accompanying S-57 → S-101 conversion, and to substantiate existing approaches to ENC production during the transitional dual-fuel period, considering the broader requirements of practical implementation.

3 MATERIALS AND METHODS

Methodologically, this study is based on a comparative analysis of normative, technical, regulatory, and scientific sources devoted to the development of IHO standards for marine cartographic data. The corpus of materials includes standards and supporting documents within the S-57/S-100 framework, materials on S-57→S-101 conversion and transitional production architectures, in particular the approaches proposed by NOAA, as well as documents defining the broader regulatory context of ECDIS use, including the STCW Convention, the ISM Code, and IMO and IHO transition decisions.

Within the analysis, three interrelated steps were applied. First, a comparative characterization of the S-57 and S-101 standards was carried out at the level of the data model, object vocabulary, portrayal mechanisms, exchange mechanisms, metadata, validation, data protection, and interoperability with other S-100 products.

Second, the conversion of cartographic data from S-57 to S-101 was examined, with a focus on typical semantic and technological divergences, the limitations of automatic conversion, and the need for manual correction.

Third, approaches to ENC production during the transitional dual-fuel period, when S-57 and S-101 products must be maintained simultaneously, were analyzed, and broader implementation barriers extending beyond purely technical readiness were outlined.

In this context, the dual-fuel mode gives rise to a distinct set of challenges, ranging from the impossibility of direct transformation of update files and semantic divergences during conversion to the need for product-neutral databases, new validation schemes, updated data-protection mechanisms, and interoperability assurance.

The study proceeds from the premise that dual-fuel should be understood not as a temporary technical inconvenience, but as a distinct production problem that subsequently extends to the regulatory, organizational, and operational levels. Accordingly, the results are organized into two thematic blocks: first, the normative and model differences between S-57 and S-101; second, conversion problems and dual-production architectures. To visualize the time frame of the transition, a scheme of normative and analytically inferred milestones was also used, making it possible to distinguish officially established deadlines from research-based assumptions regarding ecosystem maturity.

In Figure 1, official dates are separated from analytical windows. This distinction is important for interpreting the dual-fuel transition, since it makes it possible to avoid conflating mandatory regulatory reference points with forecast assessments of ecosystem readiness, dependence on test datasets, type approval, and market availability.

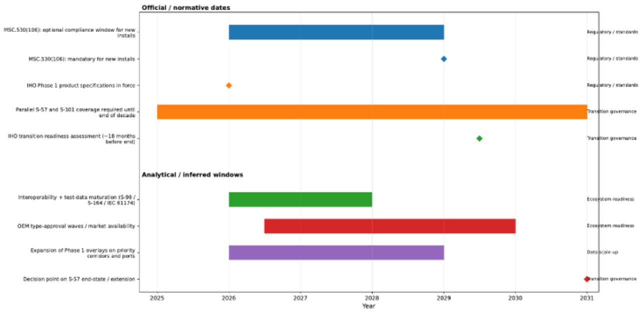

Figure 1. Indicative timeline of the transition to global S-100 implementation (2025–2030), distinguishing normative milestones from analytical assumptions. Note: bars under 'Analytical / inferred' are scenario-building assumptions derived from official dependency chains, not formally mandated dates. Source basis: [10]-[13].

4 RESULTS

4.1 *Comparative Characteristics of the S-57 and S-101 Standards*

According to the analyzed materials, S-57 and S-101 differ not only in the technical format of data sets, but also in the standard architecture to which each belongs. S-57 represents the earlier ENC regime built around the S-57 transfer standard and its associated ENC product specification, whereas S-101 has been developed as an S-100-compliant ENC product specification intended for use within the broader S-100 framework.

A more concrete difference concerns how the content of the ENC is formally specified. In S-57, Appendix A provides the official Object Catalogue, that is, the data schema of the transfer standard, while Appendix B contains the product specifications applicable to particular applications, including ENC [14]. In S-101, the product specification states that the application schema is realized in the Feature Catalogue, which describes the feature types, information types, attributes, attribute values, associations, and roles that may be used in an ENC supporting controlled versioning, formal validation, and greater semantic consistency of the feature vocabulary [15]. The Feature Catalogue is available as an XML document, while Annex A constitutes its human-readable interpretation. In practical terms, this means that, in S-101, the semantic structure of the ENC is packaged as a formal S-100 product component, rather than being divided between the transfer standard and separate ENC-specific rule documents in the S-57 manner.

Portrayal follows a similar logic: in S-57 it is defined externally through the S-52 standard and implemented largely through software developers' interpretation of that standard, while S-101 is supported by its own Portrayal Catalogue as a machine-readable rule set that helps standardize the application of conditional symbology across different implementations [15], [16].

The exchange model also differs substantially. In S-57, the exchange set consists of a single catalogue file (CATALOG.031) and data-set files, including the base file (.000) and successive updates (.001, *.002, etc.), but does not include either the feature catalogue or the portrayal catalogue. By contrast, S-101 delivery is organized according to the S-100 Exchange Set scheme, which may include feature and portrayal catalogues as well as service descriptions (Exchange/Discovery Catalogues), thus making delivery more self-sufficient from the standpoint of semantics and visualization [14], [15].

Additional differences concern scale handling, object relationships, maintenance logic, data protection, validation, and interoperability. Whereas S-57 relies on SCAMIN/SCAMAX attributes and historically established usage bands, S-101 introduces new standardized "minimumDisplayScale"/"maximumDisplayScale" attributes together with a formal Dataset Loading Algorithm, ensuring reproducibility in the selection of coverages and greater control over system behaviour during scale changes in the context of S-100 framework. [14], [15]. At the model level, S-57 does not provide named relationships between objects; where several objects must be related, collection objects such as C_AGGR or C_ASSO are used as containers for functionally linked entities, for example pairs of leading lights or elements of traffic separation schemes [14]. S-101, by comparison, supports named associations and information types, thereby deepening the descriptive capacity of the model and improving interoperability, that is, the compatible and stable use of data across different systems [15].

The two standards also differ in their developmental logic. The evolution of S-57 has effectively stabilized at Edition 3.1 and proceeds mainly through maintenance documents, whereas S-101 continues to develop as a product specification with a clear system of editions, revisions, and clarifications coordinated within the broader S-100 framework.

Data protection and licensing reflect the same shift: S-57 has historically relied primarily on S-63, while S-101 is integrated with S-100 Part 15 ("Data Protection"), thereby aligning security approaches across the S-100 product family [17]. Quality assurance is likewise more formalized in S-101. While S-57 checks were historically standardized through separate lists such as S-58, S-101 contains formalized validation checks in Annex C, which facilitates automation and is consistent with the general methodology of S-100. This broader logic of integration is also reflected in the operational role of S-101. Unlike the mono-product nature of S-57-format ENCs, S-101 is designed for use within the broader S-100 environment and for coordinated operation with other products such as S-102, S-104, and S-111 in accordance with the interoperability requirements of S-98 [15], [18].

Structurally, S-100 is not simply a "new chart format," but a universal hydrographic framework in which the basic standard is separated from specific product specifications. Its architecture encompasses the geospatial registry and concept vocabularies, machine-readable feature catalogues, metadata and data-quality models, exchange mechanisms, portrayal catalogues, and data-protection mechanisms. Within this system, S-101 is only one of the products, whereas S-98 plays a coordinating role by establishing principles for the joint use and portrayal of S-101 together with S-102, S-104, S-111, and other layers in the S-100 ECDIS environment [15], [18]. For that reason, the dual-fuel question is not limited to a comparison of two ENC standards but is embedded in the broader problem of how the multilayer S-100 stack functions.

Accordingly, the most significant differences between S-57 and S-101, together with their place within the broader S-100 architecture, are summarized in Table 1.

Table 1. Comparative Characteristics of the S-57 and S-101 Standards.

Aspect	S-57 (ENC)	S-101 (S-100-based ENC)
Basic nature of the standard	A standard with a fixed model and structure; the single previous-generation ENC standard. The ENC specification is described in appendices.	An ENC product specification based on S-100. It is the basic navigational layer for S-100 ECDIS and is intended for joint operation with S-102, S-104, S-111, etc.
Schema definition	Object Catalogue provides the official data schema of the transfer standard; ENC-specific constraints are further specified in the ENC Product Specification.	XML Feature Catalogue that formally defines feature types, information types, attributes, values, associations, and roles; Annex A provides the human-readable interpretation.
Portrayal	Separate S-52 standard; not included in the dataset.	XML Portrayal catalogue, which may be supplied together with the data through the Exchange Set.
Portrayal rule mechanism	S-52 correspondence tables and algorithms; generally not machine-readable.	Support for scenario-based rules (via the Lua language) in the Portrayal Catalogue.
Dataset encoding	ISO/IEC 8211 profile; base .000 files and updates *.001, *.002, etc.	Encoding under S-101 on the basis of S-100 and an XML exchange catalogue.
Exchange package for data delivery	The exchange package consists only of data and does not include feature / portrayal catalogues.	S-100 exchange packages may include feature catalogues, portrayal catalogues, and auxiliary files.
Associations and information types	Limited relationships; collections of objects such as C_AGGR, etc.	Named associations and information types provide richer semantics.
Metadata and quality	Metadata at the dataset or catalogue level.	Comprehensive metadata and quality schemes in the context of ISO 19115/19157, inherited through S-100.
Versioning and maintenance	Edition 3.1; subsequent changes are introduced through maintenance documents.	Formalized editions, revisions, and clarifications; maintenance within the S-100 framework.
Data protection	S-63 for protection and licensing of S-57 ENCs.	S-100 Part 15 for S-100-based products.
Checks / validation	Recommended checks, including S-58 for S-57 ENCs.	Annex C – S-101 Validation Checks; further formalization through S-158.

4.2 *Constraints of S-57→S-101 Data Conversion and dual-production architectures*

In the context of implementing the new framework of cartographic data standards, the question of S-57→S-101 conversion becomes especially relevant. IHO guidance documents [19] describe typical conversion problems, including object mapping, the transfer of textual information to the corresponding S-101 information types, semantic discrepancies, and differences in relationships between objects. They also emphasize the need to normalize certain S-57 classes prior to conversion in order to increase the proportion of automatically convertible data.

The existence of ready-made conversion tools confirms the technical feasibility of such a transition, but it does not eliminate the problems of divergent outputs and potential data loss. Several studies note that automatic conversion has clear limits of applicability and that errors or omissions may affect navigational safety. For this reason, the results of conversion require additional checks and manual correction.

The IHO Conversion Sub-Group report defines objectives for increasing the consistency of S-57 data in order to raise the share of automatically convertible data [20] and identifies classes that require normalization prior to conversion. The National Oceanic and Atmospheric Administration (NOAA) presented a transition plan from S-57 to S-100 [21], comparing several strategies: direct conversion, maintaining two separate databases, complete abandonment of legacy standards, and the creation of a product-neutral database. Among other things, the plan highlights the impossibility of direct transformation of S-57 update files and indicates that generating both products in a dual-fuel mode is more efficient than maintaining S-57 alone with continuous conversion to S-101. In turn, ArcGIS Maritime offers a ready-made conversion tool [22], which confirms the technical possibility of implementation, although it does not eliminate discrepancies and errors arising during the process.

Studies [23], [24] likewise indicate that, despite the relevance of the proposed methods, automatic conversion remains limited in its applicability, while errors and data loss may affect navigational safety. Consequently, conversion should not be understood as a one-time automated procedure, but as a multi-stage process involving prior preparation of S-57 data, automated transformation, validation, and subsequent human review.

In this context, NOAA outlined an architecture (Fig. 2) that combines the preparation of S-57 data for conversion, automated transformation into S-101, and subsequent loading into a product-neutral database from which data may be exported in both S-57 and S-101 formats [21]. In this scheme, the earlier S-101 stage represents converted input prepared for database loading, whereas the later S-101 stage denotes final product generation.

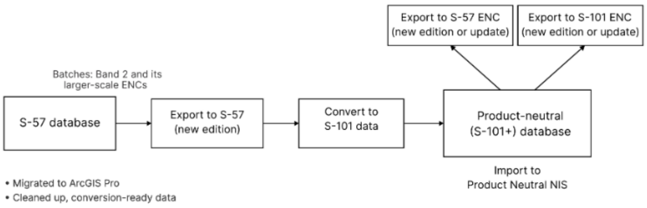

Figure 2. Basic components of the NOAA ENC production system using two product databases [21]

Practical testing of the IHO/ESRI/NOAA converters [23] made it possible to identify those elements that are converted relatively successfully and those for which systematic discrepancies arise. This confirms that the transition from S-57 to S-101 cannot be reduced to a purely technical format transformation.

One of the central issues in the transition from S-57 to S-101 is the choice of production architecture. The NOAA transition plan compares several strategies [21]: maintaining a single S-57 database with subsequent conversion to S-101, transitioning to a single S-101 database, maintaining two separate databases, or constructing a unified product-neutral database. Comparison of these approaches shows that dual-fuel should be understood not merely as a temporary phase in the coexistence of two standards, but as a distinct problem of organizing ENC production, maintenance, and updating.

In light of the analyzed sources, the most effective long-term approach appears to be the architecture outlined by NOAA, which combines the preparation of S-57 data for conversion, automated transformation into S-101, and subsequent loading into a product-neutral database from which both products may be generated directly [21]. At the same time, this option is also the most resource-intensive at the implementation stage. The key conversion-related issues identified in the analyzed sources are summarized in Table 2.

Table 2. Summary of the Key Problems of S-57→S-101 Conversion

Problem	Manifestation in the conversion process	Consequence for the dual-fuel workflow
Semantic discrepancies	Not all S-57 objects, attributes, and textual elements have direct and unambiguous counterparts in S-101.	The need for normalization rules, semantic mapping, and manual post-processing increases.
Different tool results	Different S-57/S-101 converters may yield different results for the same data.	Ensuring consistency of products across different production lines becomes more difficult.
Limitations of automatic conversion	Automatic conversion does not cover all cases without losses or errors.	Additional checks, human review, and local corrections after conversion are required.
Indirect transformation of update files	S-57 and S-101 update files are not subject to direct reciprocal conversion.	Updates become a separate production problem rather than a simple consequence of converting base cells.
Need to normalize source data	Some S-57 classes and structures require prior ordering before conversion.	Without preparation of the source data, the share of data suitable for automatic conversion decreases.

4.3 *Discussion*

The results obtained indicate that the transition to S-100 constitutes a systemic shift in the production, distribution, and use of marine cartographic data. For the industry, this means not a linear upgrade of S-57, but the deployment of a multi-product environment in which S-101 coexists with other S-100 products under the interoperability framework defined by S-98. In such a configuration, production architecture becomes no less important than the data model itself, since errors arising at the producer-side stage may propagate to subsequent levels of the stack.

The key changes for hydrographic offices and ENC publishers concern the way data are modelled, and production databases are constructed. Formats S-100/101 rely on machine-readable feature catalogues and portrayal rules, which makes rigid hard-coding of symbology impossible and requires controlled catalogue management and updating. During the transitional period, production databases must either be maintained in parallel for S-57 and S-101 or be transformed into product-neutral schemas. The latter approach minimizes discrepancies between products but requires the largest one-time investment in schema design and data migration.

Quality-control procedures are also undergoing revision. Whereas for S-57 test datasets and checks described in S-58 have traditionally been applied, for S-101 the emphasis shifts to formalized validation checks, including Annex C and the S-158 validator series. This shifts the focus from purely syntactic errors to semantic and topological consistency, control of associations, verification of boundary intersections, and correctness of portrayal.

The implications, however, extend beyond data producers. For ECDIS manufacturers, the transition to portrayal engines capable of dynamically interpreting feature catalogues and portrayal rules, as well as ensuring interoperability among S-101, S-102, S-104, S-111, and other layers, becomes critical. It is precisely at this point that the significance of S-98 comes to the fore, since the issue is not merely the technical superimposition of several layers, but the application of formalized rules governing their priority, compatibility, contextual display, and conflict management. Accordingly, producer-side bottlenecks may be transformed into user-facing consequences, including differences in portrayal, instability of updates, the complexity of product integration, and new requirements for bridge practices.

Another implication of interoperability concerns the practical usability of integrated multi-layer portrayal. Since the S-100 environment is designed for the coordinated display of several interoperable products, the expansion of available layers may raise questions regarding the clarity of presentation, the management of information density, and the ease with which navigators interpret information under operational conditions. In this sense, the significance of interoperability is not limited to technical compatibility alone but also extends to the practical conditions of information use on the bridge. This aspect is especially relevant during the transitional period, when new portrayal logics are being introduced alongside established operational routines. Although the issue lies beyond the direct scope of the present study, it represents a plausible implementation challenge that merits further examination in connection with interoperability, bridge ergonomics, and practical ECDIS use.

However, even a technically sound S-100 stack does not guarantee problem-free implementation. Questions remain concerning crew training and familiarization, the revision of bridge procedures, the proper allocation of responsibility among data producers, distributors, OEM manufacturers, and shipping companies, as well as alignment between regulatory requirements and the actual maturity of software and test datasets.

Thus, dual-fuel should be interpreted as a distinct research and production problem. Its substance lies not only in the parallel maintenance of two ENC formats, but also in the need to ensure semantic consistency, stable validation, predictable update logic, compatibility of data-protection mechanisms, control over discrepancies between end products, and an acceptable level of operational readiness of the systems that consume these data.

Accordingly, S-100 should at present be characterized as a normative and technical framework that has already formally entered into force and moved into a phase of practical implementation. The IHO officially put the first phase of the S-100 product specifications into force on 1 January 2026 and explicitly indicated the possibility of their production, testing, and use in the operational environment.

At the same time, this does not mean that S-100 ECDIS has already reached full operational maturity as a mass commercial solution. Although the new IMO standards opened the possibility of voluntary use of S-100 ECDIS from 1 January 2026 and provide for its mandatory application to new installations from 1 January 2029, the currently available IHO materials indicate that the supporting framework is still being refined, particularly in the areas of interoperability and testing. This suggests that S-100 ECDIS should not yet be regarded as a fully mature mass commercial solution for vessels subject to SOLAS requirements. Therefore, the current state of S-100 should be defined as one of real, but still incomplete, implementation: formally, the standard is already suitable for practical use and is being applied in test and selected operational scenarios; however, its full-scale integration into everyday shipboard practice is still constrained by certification, technical, and infrastructural factors.

5 CONCLUSIONS

The transition from S-57 to S-101 is not merely an update of the ENC format, but a shift to a new logic of modelling, portrayal, validation, protection, and distribution of marine cartographic data within the broader S-100 framework.

In this context, although automatic S-57 → S-101 conversion is technically possible, it is accompanied by semantic discrepancies, heterogeneous outputs from different tools, the need to normalize source data, and mandatory human review. A particularly critical limitation is the difficulty of direct reciprocal conversion of update files, which complicates support for both products during the transitional period.

From the standpoint of practical use, the simultaneous portrayal of several S-100-based products raises an additional human-factors issue: the need to control screen complexity and information overload. This question is especially important during the transitional period, when interoperable portrayal rules are still being operationalized and the practical implementation of S-100 ECDIS remains at an early stage. For that reason, the ergonomics of multi-layer display and the cognitive effects of integrated portrayal warrant separate empirical study.

In summary, even if the technical S-100/S-101 stack is fully equipped with the necessary converters, validators, and portrayal mechanisms, practical implementation will remain complicated by a number of broader problems. These include user training and familiarization, revision of standard bridge procedures, allocation of responsibility and liability for data and portrayal errors, regulatory alignment between IMO/IHO/IEC requirements and the actual readiness of the market, the maturity of OEM software, the availability of representative test datasets and a type-approval baseline, as well as the organizational readiness of hydrographic offices, flag administrations, distributors, and shipping companies.

Therefore, the success of the transition will be determined not only by the quality of producer-side solutions, but also by the degree of coherence across the entire ship-shore implementation chain.

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