Naval Fleet Integrated Logistic Design optimization: the Italian Navy experience in enhancing feedback from the field

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Abstract. Defense budget are shrinking and human resources are becoming more critical, while operational needs of Warships increase and change in the life cycle to face new threats.
To achieve the best balance between operational availability (Ao) and costs all along the life cycle, the sustainability requires a correct initial definition of the support followed by its continuous optimization, guaranteed by constant monitoring and analysis of the data coming back from the field, by a review of the reliability parameters, maintenance plan and spare parts list.
The ITN (Italian Navy) started a change management initiative from beginning of 2000' through an optimization process by analysing the return from the field data during the TGS FREMM contract, which has lasted for more than 10 years.
This process consist of:

- An initial definition of the support: configuration management, obsolescence monitoring, maintenance plans and definition of stocks, optimized with OPUS10 tools, whose models are created starting from the logistic databases provided by the private industry;
- The evaluation and analysis of return from the field data: measure of the reached availability, KPIs (Key Performance Indicator) evaluation and reliability calculation, trough assessment software tools (Weibull) and recalculation software (Calypso);
- The optimization of support: in terms of operational availability and costs, in compliance with the operational requirements.

After the FREMM experience, ITN is taking over all the activities performed so far by the private companies, for current and future shipbuilding programs (LSS, PPA and LHD).
The authors will go through the process set, tested for FREMM program, will show results after more than 10 years of experience, and will cover all the activities Italian Navy is taking care by itself for new programs, mentioning as well ITN investments and available tools.

Keywords. Italian Navy, ship design, support definition, reliability, logistic support engineering

1. Introduction

Navies budget constraints, combined with increasingly ambitious operational requirements for naval vessels, have made unavoidable foreseeing since the

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preliminary phase of the naval design, an integrated logistic design of the vessel, as a complex "system of systems", to make definition and management of support more and more efficient, supported by a continuous optimization process, through either constant from the field data monitoring and analysis, and reviewing reliability parameters, maintenance plans and spare parts list in accordance with the experience coming from the operational service.

ITN has begun to undertake change management since 2000 ' with the acquisition contract of the FREMM class naval units (Frigate European Multi Mission) and the contextual In Service Support (ISS) contract signed with contractor (TGS - Temporary Global Support).

The support definition and management processes, previously consolidated in the Navy field, namely:

- the sizing of stocks dictated by the NAV80 regulation (Legislation for Stock Sizing in force until 2014);
- the technical manuals in paper and un-editable form;
- the configuration data of the devices in spreadsheet format;
- the evaluation of fault data by reading the documents on the efficiency of the systems issued by the board (AVREP - Failure Report);

are nowadays replaced, thanks to the use of dedicated logistic ITN systems and software (either created for this purpose or by using a license for an already existing tool), by:

- Processing of the logistic input data, provided by the contractor, through the use of SIMPLICIO software for the coding and processing of the Joint Logistic Support Data Base (JLSDB) and Common Source Data Base (CSDB), developed with standard S1000D ™ and S3000L specifications ™ that implements an interface MIL-STD-1388 2B;
- Management and loading of systems and equipment configurations, maintenance plans, logistic data, computerized technical manuals, return data from the field and administrative and cost data, through the creation of a SLIM (integrated logistic software suite, Figure 1), based on the SAP® platform consisting of the following tools:
    - The Shipyard Automation Management Information System (SIGA) monitoring costs relating to maintenance activities
    - The Supply Chain Management Information System (SIM) for materials and spare parts management (withdrawal, transfer and stock monitoring), materials identification and NATO coding, materials movement orders;
    - The On-Board Maintenance Management Information System (SIGAM), providing all information relating to plants, systems, subsystems, equipment Configuration and Technical-Logistic Data Visualization; providing automatic management of all maintenance tasks and scheduled inspections of all systems / equipment by on board personnel;
    - The Naval Support and Experimentation Center Information System (SIC) to support and manage "In Service Support Engineering Processes", interfaced with all the other software mentioned above and with which it shares a single material database, allowing Configuration Management operations, Obsolescence management, Support Performance Evaluation, Documentation Management, return Data from the Field analysis;

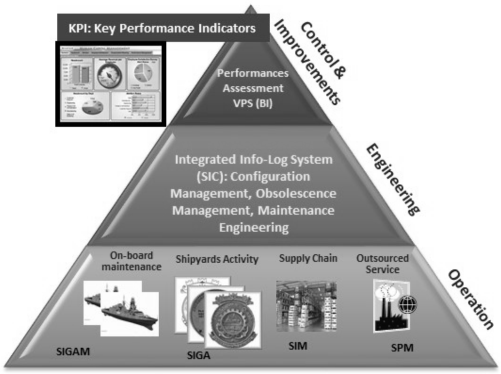

Figure 1 – Integrated logistic software suite (SLIM)

- The Service and Portfolio Management (SPM) to support planning and management, control and report activities. The SPM system controls the processes regarding the activities of maintenance, engineering support and material management, in order to fit in with the policy of the contract.

- Stock sizing based on the operational needs of the naval unit, resulting from the optimization of operational availability (respect to cost) through the use of the OPUS Suite software (developed by Systecom);
- Computerization of technical manuals created in html for use in "X-browser" (Technical Publication DB) which can be updated and viewed from all ITN organization elements;
- Evaluation of the operational availability of the vessels class using dedicated tools (OAMD and DiOp_Miss (Operational Availability Measure Device) made by Orizzonte Sistemi Navali);
- Reliability assessment with software tools (Weibull®, Calypso (tool developed in R by Pangea), and additional tool based on Open Source Knime software) starting from the fault data;
- Condition Based Maintenance analysis through the L-CBM software (developed by Seastema (Fincantieri Nextech S.p.A)).

As during the FREMM program, ITN supervised the Contractor in all the mentioned processes, from the initial design phase of integrated support to the subsequent analysis of the return data from the field and evaluation of the KPIs (Key Performance Indicators). Now ITN is carrying out by herself all the ISS activities, tailoring them to the ITN logistic requirements for the upcoming naval acquisition programs (i.e. LSS, LHD and PPA).

In accordance with the internal quality plans, ITN has incorporated the activities mentioned above into the Support Logistics Engineering processes, developing an internal flow that can be summarized in the following steps:

- Configuration Management
- Definition of Support
- Collection and analysis of data in operation
- Optimization of the LD (spare parts list) and of the LCC (Life Cycle Cost).

2. Configuration management

Within naval program contracts ITN purchases, besides the design itself, the logistic design as well, including all logistic reports, reliability models and studies preparatory to have available all the following information essential to start loading an appropriate data base into the ITN software tools:

- logistic databases (BDL) for each equipment installed on board;
- technical manuals and related corrective and preventive maintenance plans associated with spare parts and tools needed;
- reliability shaping through RBD models.

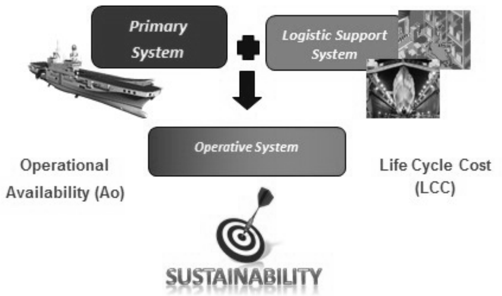

Figure 2 - Operative system composition

During the preliminary phase of the naval program, while preliminary manufacturing is running, ITN proceeds on her own to carry out:

- Verification of the data consistency;
- Loading BDLs into the ITN Software systems (SIC - SIGAM) and the technical manuals into the "X-browser" system;
- Identification of the items associated with a preventive or corrective maintenance task;
- Association of the maintenance task with the skill of the operator in order to identify those to be assigned to the board team and those to the staff of the naval shipyards;
- Verification of maintenance plans.

Once these operations have been completed, the support definition phase can start.

3. Support definition

The support – in terms of proposed spare parts list - is defined during ship design phase by the single equipment design authority, and reassessed / optimized downstream of the reliability, availability and supportability analysis by having access to the return data from the field.

For the spare parts Lists (LD) definition, ITN uses OPUS10 software, which allows optimization of purchases in accordance with operational requirement and budget constraints. The software has a user interface based on tables, each of them characterized by mandatory and optional fields. Some tables allow modelling the functional organizational structure of the ITN (Figure 3) allowing:

- To define the on-board warehouses of the naval vessels;
- To define the ground warehouses spread over several operational sites;
- To introduce the Navy organizational structure with the relative execution times for the activities on board, shipyards, warehouses and contractor;
- To define the duration and number of missions for each vessel while considering the ship during the mission will be able to count only on the on-board warehouse;
- To implement the maintenance skill (crew / shipyard);

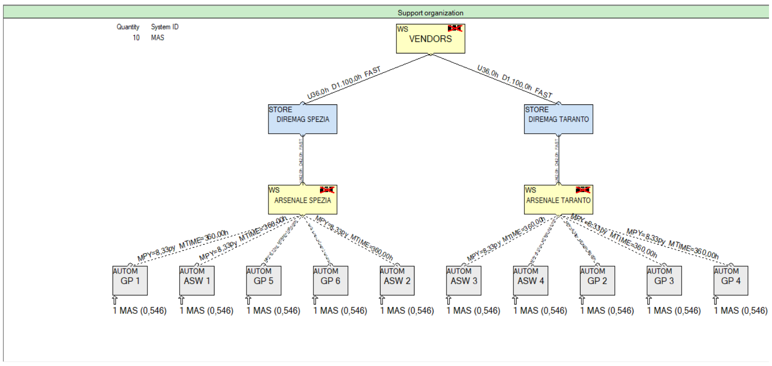

Figure 3 - ITN organizational structure of board, shipyards and warehouses

Other tables allow inserting Equipment data taken from logistic databases. Specifically, for each item:

- Part Number, description and quantity of items per system;
- MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair)
- Supply price and repair price (optional)
- Delivery time and repair time
- Type of item that can be repaired/replaced and ground edge maintenance level
- Percentage of use (duty cycle)
- Functional dependencies (reliability block diagram – RBD)

The output of running the software is an operating availability/cost curve (Figure 4).

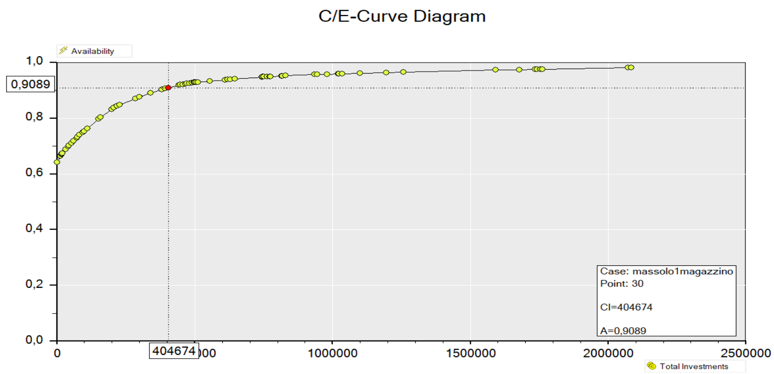

Figure 4 – Parts list on the availability/cost curve

Each curve point represents an optimized parts list, which, in the face of an initial purchase cost of spare parts (abscissa value), allows reaching the average availability value (ordinate axis). Moving along the curve it is possible choosing the list compliant with the required operational availability or budget constraints. On the other side, when a budget limit is present, it is possible to get an optimized value of availability. The curve is of asymptotic type: the operational availability will tend to a maximum value meaning that, near the asymptote value, the increase in cost will correspond to a minimum increase in operational availability. The asymptote value is strongly influenced by mission duration, by MTBF values and by their associated maintenance task that can be performed by a ground-level skill. During the mission, only maintenance involving an on-board skill can be performed.

If the required availability cannot be reached for all the suitable budget value, a proposal for a technical modification of the system might be done to Design Authority.

The LD generated by the described process becomes the purchase list of the stocks needed by the naval vessel in order to be able to perform preventive and corrective maintenance tasks either at sea (parts on-board) and berthed (ground warehouses).

Nevertheless, the provisioning list is a fluent document subject to continuous revision in accordance with the from the field data evaluation.

4. Collection and analysis of in-service data

The in-service data collection takes place through the on-board ITN systems holding information about failures occurred on a single item; systems running hours; reports of discrepancy between items actually installed on board and items foreseen in the configurations and in the technical manuals; differences between the maintenance tasks envisaged and those actually executable; obsolescence information provided by the Design Authority.

Collected data can produce the following effects:

- Changes to the technical documentation that do not impact on the stocks redefinition or maintenance plans;
- Changes to maintenance plans or procedures that involve a redefinition of the support (also involving stocks redefinition);
- Checks on operational availability and reliability data measured compared to requirements value, which could involve more in-depth analyses at the system level or deep to a single item level and affecting the revision of the logistical parameters (and therefore the revision of the support).

The fault data collection allows also to enhance:

- Operational Availability (see Chapter 5)
- Reliability of the Systems/Equipment, and related Sub-Assemblies or specific items.

4.1. Reliability analysis

The reliability and revaluation analysis of the MTBF values is performed by using the following ITN tools and software:

- Dedicated dashboard monitoring equipment reliability, which is based on Knime open source software;

- Weibull® software: to evaluate whether the observed MTBF value is within the foreseen MTBF distribution;
- Calipso software (custom created for ITN): to redefine a new MTBF value based on both the failure and non-failure conditions by means of the Bayesian inference. The higher the observation time, the more reliable this process is.

The results of the analysis and the new calculated MTBF values (deriving from the re-evaluation of the expected MTBF values compared to the observed MTBF values), imply the redefinition of the support (by applying the new values to the OPUS software) and, consequently, the LD curves re-plotting, as a function of availability / cost.

4.2. Obsolescence monitoring

The above analyses and evaluations are integrated with a continuous activity of obsolescence monitoring. Specifically, this process can take place either in the materials purchase process or as a result of the obsolescence registers supply, provided by support contracts (Industries). For each obsolete item, it is evaluated:

- If it is still available for purchase in LBO (Last Buy Order) and if so, until when.
- If the obsolescence concerns also the reparability and, in this case, an assessment of the residual reparability percentage is carried out;
- The number of items installed in the ITN systems and their presumed modernization or disposal date;
- The warehouses stocks;
- AOR (Annual Operating Rate) of operation;
- Supportability time required before all item disposal.

4.3. Supportability analysis

With the above collected data, a supportable analysis is carried out on the single item by the calculation of the number of items necessary to ensure a probability of sufficiency > 90% for the entire item life (until disposal). If the necessary quantity is allocated in the warehouses or can be purchased in LBO, the eventual purchase is carried out. Otherwise, actions are taken to redesign the item. In the event that the number of items to be purchased is higher and involves a high outlay, an evaluation of the convenience is carried out in relation to a possible redesign. The above actions involve a reassessment of the support and specifically they imply a modification of the following data entered in the OPUS tool:

- Reordering time of the item greater than the life time of the system (in the case of LBO)
- Maximum quantity admitted in the warehouses equal to the current warehouse stock + any LBO (in the case of LBO)
- Item reordering time equal to the redesign time + first supply (in the case of redesign)
- Maximum quantity allowed in the warehouses equal to the current stock (in the case of redesign)

5. Support and LCC optimization; operational availability evaluation

The design of the logistic support, carried out in order to meet the operational availability requirements dictated by the ITN, requires continuous review and optimization through the analysis processes of the return data from the field, to the analysis of obsolescence and to the analysis of reliability and sustainability, as detailed in the previous Chapters. The ultimate purpose of the aforementioned processes is to make the vessel able to easily meet availability requirements even by reviewing some equipment design. This is the outcome of a robust logistic design followed by an effective In-Service Support, leading to an optimized Life Cycle Cost of the asset.

Figure 5 - Life Cycle Cost phases subdivision

5.1. Operational Availability assessment

Assessment of operational availability is carried out as well. The analysis is performed basing on the functional block diagrams (RBD), the type of operational missions and the operating status of the systems. They allow to statistically calculating the operational availability at sea. The output data makes it possible to assess whether the required requirement is met or not and, if not, identify which system has determined its criticality in order to subsequently perform a detailed reliability analysis.

6. Conclusion

Thanks to having implemented Logistic Design within the Naval Design, Italian Navy is now able to fully perform Support Engineering processes, making possible optimization and cost-effectiveness of choices done in running the most recent part of the Fleet.

First good results have come back from this virtuous approach.

The skills acquired to identify the optimal spare parts and cross-examination capability versus Design Authority proposals in managing obsolescence have made the ITN to make sensible money savings.

Further steps are being done in the near future like as some growths in the ITN tools, useful to mitigate some issues revealed in running the process.

Acronyms

AOR	Annual Operating Rate
AVREP	Failure Report
BDL	Logistic Data Base
CSDB	Common Source Data Base
DA	Design Authority
DB	Data Base
FREMM	Frigate European Multi Mission
ISS	In Service Support
ITN	Italian Navy
JLSDB	Joint Logistic Support Data Base
KPI	Key Performance Indicators
LBO	Last Buy order
L-CBM	Land Condition Based Maintenance
LCC	Life Cycle Cost
LD	Spare Parts Lists
LHD	Landing Helicopter Dock
LSS	Logistic Support Ship
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
OAMD	Operational Availability Measure Device
PPA	Multipurpose Patrol
RBD	Reliability Block Diagrams
SIC	Naval Support and Experimentation Centre Information System
SIGA	Shipyard Automation Management Information System
SIGAM	On-Board Maintenance Management Information System
SIM	Supply Chain Management Information System
SLIM	Integrated Logistic Software Suite
SPM	Service Portfolio Management
TGS	Temporary Global Support

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