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Traditio et Innovatio

# Product Business Assurance in the Marine Equipment Supply Industry with Focus on Essential Ship Systems

**Almir Becirspahic**

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Supervisor: Prof. Robert Bronsart, University of Rostock

Reviewer: Prof. André Hage, University of Liege

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## **Declaration of Authorship**

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Where I have consulted the published work of others, this is always clearly attributed.

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## **ABSTRACT**

With the associated changes in the regulatory framework, the increased complexity and introduction of more and more ‘smart manufacturing’ of maritime systems there is an increased demand for enhanced processes in product assurance following the principles of supply chain and best practice. The product quality assurance has been identified as one of the most important issue.

Thus, it is very challenging to define what can be a possible direction or strategy of a global operating marine supply industry, considering the drivers of global economies in the near future, and what challenges and difficulties the global marine supply industry has to overcome to maintain the high level of safety and reliability of their products.

One objective of the thesis is therefore to review the currently applied marine product certification processes in comparison with processes as applied by other different industries (Automotive and Aviation industries) with the aim to compare their product assurance processes with those currently applied in ship classification.

In order to discuss the different business models and describing key performance indicators (KPIs) the main differentiators in providing business assurance between some of the leading class societies will be discussed by looking for best practice in applied processes and procedures.

The main focus of the thesis however is to identify potential options for alternative means of providing product assurance within the marine supply industry, taking into account best practices in each of the industries, current and the adopting and willingness to change using emerging technologies, e.g. providing improved product traceability in product marking by using an alternative process and replacing traditional society stamps.

A proposal for an alternative certification service model is eventually discussed as an opportunity for a change in the direction of future product assurance processes with the aim to support the Marine supply industry by maintaining their high standard in product assurance as expected by their customers.

In terms of emerging technologies and to support this new model the RFID technology is explained as providing the technology for enhanced product marking and subsequently improved traceability of e.g. safety critical products of the marine supply industry.



## 1. INTRODUCTION

The European Marine supplies industry plays an important role in the steadily increasing and complexity high level reaching global marine market. Especially the marine supply industry is to be seen as a kind of “engine” for some economics in Europe if not at global level. The size of the business in 2011 has been given to 43,8 billion EUR (including export production) alone in Europe, providing employment for about 342.000 persons as outlined in a Study about the competitiveness of the European marine supplies industry.[15]

The heterogeneous structure of this important part of the maritime industry is described by a comparably high number of different manufacturing companies and locations, including a high number of small and medium-sized enterprises (SME) with a high degree of competition. This is becoming even more important taking the fact, that the majority of ship new-building contracts including new-construction of complex Offshore installations have moved to Asia. As a consequence the European marine supply industry was forced to operate more global, i.e. to shift manufacturing to Asia. Still the European marine equipment supply Industry has a leading position, but there is a need to review and further develop new business strategies to secure and increase where possible market share in an increasingly competitive market.

The European marine supplies industry could be also seen as the technology innovator and driver.

The well-developed value chains in the shipping industry with regard to the spare part business is another important aspect. It is essential that suppliers operate very costs efficient and provide highest quality outcome of their products which allows just in time serving of needs within the supply chain of a global operating market.

Safety and reliability of their products are therefore most important for the marine supply industry and to secure this is the task of international operating Classification societies. This is supported by regulatory schemes like the international conventions SOLAS and MARPOL.

To that end classification societies have developed prescriptive rules and procedures which manufacturers of marine equipment need to be in compliance with to ensure that the requirements of high safety standards and international conventions are met.

In today's fast changing supplier markets the requirements for a permanent high quality of products forcing companies to introduce processes and procedures to validate and demonstrate compliance with these issues and to increase the speed and delivery time without compromising safety.

With the changes in the regulatory framework, the increased complexity and introduction of 'smart manufacturing' of maritime systems there is an increased demand for consistent product assurance following the principles of supply chain.

## **1.1. Objectives of the Study**

The objective of this thesis is therefore to review the currently applied marine product certification processes in comparison with processes as applied by different industry and compared to the process used in ship classification. As the result a proposal for an alternative certification service as stipulated in the IACS (URZ 26)<sup>1</sup> is discussed as an opportunity for change in the direction of product assurance processes with regard to the Marine supply industry.

It is to discuss the future role of classifications societies in relation of modern product business assurance services applied as an example for essential ship systems by comparing business assurance services of related transportation industries with focus on best practice used by the automotive and aviation industry.

Also to investigate the main differentiators in providing business assurance services between some of the leading class societies by looking for best practice in applied processes and procedures.

The thesis will outline what could be best practice applied over the business assurance processes and to propose a possible alternative route to improve the efficiency of the overall maritime supply industry certification business.

Finally outline a new alternative certification proposal currently developed by the Lloyd's Register Group to better fit the industry alongside the supply chain and to add value to the benefit of clients and community.

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<sup>1</sup> IACS – URZ (26) Alternative Certification Schemes [37]



In summary the objectives are as follows:

1. Comparison of different business assurance practices applied by selected industries and the marine supply industry.
2. Comparison of business assurance services as offered by different classification societies
3. To analyze and discuss the new approach of LR and to give some practical suggestions to overcome some challenges and use opportunity, i.e. to address product marking and traceability through the introduction of well-known technology, e.g. RFID technology.

## **1.2 Methodology of the Study**

In order to achieve the objectives as mentioned above, a thesis structure proposal and information gathering research plan was made in early June 2015, and a qualitative method has been taken to obtain all the necessary data available. Because of the nature of the subject described by high complexity the scope of investigations had to be limited.

According to the proposed thesis structure the relevant literature has been widely reviewed and analyzed, including appropriate comments from consultations with the industrial partner for this thesis the Lloyd's Register Group Ltd. This also did cover relevant publications of international conventions such as IMO, technical quality standards from different industries, reports and publications, conference and seminar papers, articles from contemporary journals, books and remarks, and information from related websites. The basic and foundation of Quality Assurance problematic was to understand why it is important for any industry sector, and to have an idea how product compliance/certification services need to follow the technology trends and what will drive the future in product quality assurance (what we can expect in the future).

In addition and judged as an important source manufacturing companies and the German marine equipment association has been visited in order to get a view from the manufacturing industry incorporated. This was very helpful under the aspect that especially if a company has production lines for delivering their product for marine and another industry installations.

Finally during the conducted field study in October 2015, the author went to one of the Directors of VDMA (marine equipment) in Hamburg with a pre-prepared questionnaire to

explore VDMA's current view and situation regarding this issue and maritime supply industry challenges and the role of classification in particular.

### **1.3 Organisation of the Dissertation**

The dissertation is presented in seven chapters. Chapter I is the introductory part, in which a briefing on the Maritime supply industry problematic regarding the Product Business Assurance as well as the objectives and methodology of the study, is addressed.

In Chapter II, the Quality Assurance and Product Assurance applied in Supply Chain processes are explained.

In Chapter III, the current business models of applied product certification of the marine industry is explained in detail. It outlines how certification processes are structured, the role of rules and how complex that process is becoming. Also it is giving an overview about one essential element of the overall certification processes, the type approval scheme of different classification societies in order to show the differences and to derive best practice.

In Chapter IV, the product certification process of the different industries is explained. The focus is on two another transportations sectors, the Automotive and Aviation industry. The chapter shall give a brief overview about the different processes these industries are applying to product certification and overall quality assurance, how complex their process are and what are their common goals in quality assurance as an outcome.

Chapter V, tries to give an overview about the current practices in product assurance of chosen classification societies compared to the other industries. We want to know what is seen as best practice of different classes and also what is best practice of the different industries regarding the product certification processes applied.

It is discoursed what can be a possible direction or strategy of a global operating marine supply industry taking into account what is global tendency of industries for the future and what are the challenges and difficulties of the marine supply industry that hamper the development in this industry. Furthermore, one element of a new approach using modern technology in product marking and traceability practical will be introduced.

Finally, in the last, i.e. sixth Chapter, the findings and recommendations related to the thesis objective is summed into conclusions for the whole dissertation.

## 2. QUALITY ASSURANCE

### 2.1. Introduction

Quality assurance is defined as a planned and systematic pattern of all actions necessary to provide adequate confidence that an item or product conforms to established technical requirements. Quality assurance (QA) can be divided into two main areas: product assurance and process assurance.

Product assurance involves making sure that the final product meets its specifications. This is usually done via thorough testing (figure 2.1). It also includes verifying that the requirements are correct, the design meets the requirements, and the implementation reflects the design.

Process assurance looks at the process used to create that final product. In process assurance, QA provides management with objective feedback regarding compliance to approved plans, procedures, standards, and analyses.

Process assurance activities are performed throughout the life cycle, including product conception, design, implementation, operation, and maintenance. Process assurance will detect, record, evaluate, approve, track and resolve deviations from approved plans and procedures.



Figure 2.1. Quality Assurance blocks

Quality control has primary objective to maintain control. It focuses on monitoring, improving, and auditing the manufacturing process and product, where the performance is evaluated during operations and compared to goals during operations. The resulting information is provided to operating forces.

Quality assurance's main objective is to ensure that control is being maintained. Quality Assurance improves, supports and audits all of the company's systems, manufacturing processes and product. Performance is evaluated after operations, and the resulting information is provided to the operating forces and others like management, corporate staffs, regulatory bodies, customers, etc.

In this sense, quality assurance has a similarity to insurance. Each involves spending a small sum to secure protection against a large loss. In the case of quality assurance, the protection consists of an early warning that may avoid the large loss. In the case of insurance, the protection consists of compensation after the loss.

*Quality Assurance through Audits.* The growth of commerce introduced chains of suppliers and merchants that separated consumers from the producers. This required new forms of quality assurance, one being quality warranties. The guilds created a form of quality assurance by establishing product and process standards and then auditing to ensure compliance by the artisans.[1]

*Audit of Suppliers' Quality Control Systems.* The Industrial Revolution stimulated the rise of large industrial companies. These bought equipment, materials, and products on a large scale. Their early forms of quality assurance were mainly through inspection and test. Then, during the twentieth century, there emerged a new concept under which customers defined and mandated quality control systems. These systems were to be instituted and followed by suppliers as a condition for becoming and remaining suppliers. This concept was then enforced by audits, both before and during the life of the supply contracts.[1]

This concept created several problems for suppliers. First one was the lack of standardization, where every buying company had its own requirements regarding the quality control system, so each supplier was faced with designing its system to satisfy multiple customers. Second problem was because of multiple audits, every supplier was subject to being audited by each customer. There was no regulation about storing the results of audits into common data bank, and customers in general were unwilling to accept the findings of audits managed by other personnel. The multiple audits were especially difficult and costly to small suppliers. In last

decades, steps have been taken with regard to standardization by professional societies, by national standardization bodies, and by the International Standards Organization (ISO). Today for quality control system, ISO 9000 series of standards is widely accepted among European companies.

## **2.2. Functional Orientation of Quality Assurance Programs**

Characteristic of all quality assurance programs are three basic principles[3]:

1. Final responsibility for quality rests with the organizations that design, develop, produce, maintain, store, and issue the product. Quality assurance supports these activities by ensuring that adequate quality provisions are planned, developed, and implemented.
2. Quality cannot be "inspected" into the finished product. Quality assurance focuses its activities on the identification, prevention, and correction of unsatisfactory conditions or elements which influence acceptability of the end product.
3. Quality is defined in terms of specific requirements to be met. Such requirements must be effectively communicated to and understood by those activities whose operations may, in any way, influence the quality of the product in terms of its use, interchangeability, form, fit, function, or safety.

Quality assurance programs can be categorized in terms of the functional activities that they support. The major characteristics of the quality programs and the principal techniques and procedures employed to assure product quality are following (figure 2.2):

- Acquisition quality assurance
- Maintenance and manufacturing quality assurance
- Supply quality assurance
- Staff quality assurance

Acquisition quality assurance (In-plant) - This function ensures that contractors fulfill their responsibilities for controlling product quality in accordance with contractual requirements,

and that finished products conform to specifications. The extent of the contractor's responsibility, in terms of quality control procedures and documentation requirements, depends on the complexity of the products.

- Reviewing the contractor's production activities and capabilities,
- Reviewing the contractor's written quality or inspection procedures for adequacy,
- Evaluating the implementation of the contractor's quality or inspection system including developed sampling plans,
- Analyzing quality data to detect unsatisfactory trends or weaknesses in the quality or inspection system,
- Investigating customer complaints and deficiency reports, and providing identification of causes to appropriate activities and
- Where applicable, performing quality assurance support activities at the subcontract level

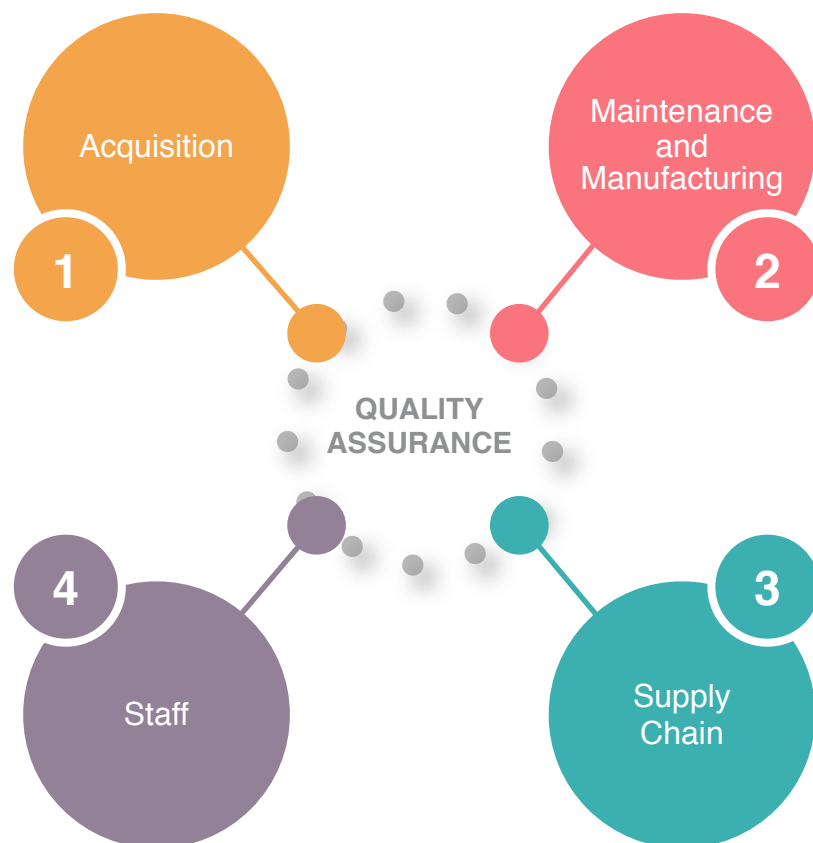


Figure 2.2. Quality assurance functions

Maintenance and manufacturing quality assurance - This function is concerned with the quality of products that are manufactured, maintained, overhauled, or modified. Major quality functions include[3]:

- Reviewing work instructions, technical data to identify characteristics critical to product acceptability, and providing inspection and test procedures
- Monitoring quality of materials and supplies required to support production activities
- Verifying product quality using sampling inspection
- Monitoring programs for controlling the accuracy of test and measuring equipment
- Evaluating procedures for maintaining control of drawings and technical data
- Coordinating the disposition of nonconforming material and
- Analyzing quality data to detect unsatisfactory trends or conditions and weaknesses in the quality system.

Supply quality assurance - This function is concerned with product quality relative to the operations and procedures for receipt, storage, preservation, packaging, packing, handling, and issue of material. The major functions of this activity include:

- Reviewing and evaluating supply systems operations and procedures through periodic audits and surveillance inspections
- Evaluating preservation and packaging procedures, processes, and equipment in supply and storage operations
- Analyzing quality data and reporting on the quality level achieved in supply and storage operations
- Coordinating disposition of defective or nonconforming products and
- Controlling the accuracy of test and measuring equipment used in supply operations

Staff quality assurance - Staff quality assurance activities are applicable to maintenance and manufacturing, supply, and acquisition quality programs and may exist - in all three functions. Since they relate and are applicable to all phases of the product life cycle, these activities may be concentrated in a separate program or organization at the command or program manager level in some agencies.

### 2.3. Quality System Certification

First users of quality assurance requirements standards were large organizations such as electric power providers and military organizations. These customers usually purchase very complex products to specific functional design. In such situations the quality assurance requirements are actuated in a contract of two parties, where the “first party” is providing organization (e.g. supplier) and the “second party” is the customer organization. Such quality assurance requirements usually include provisions for the providing organization to have internal audits sponsored by its management to verify that its quality system meets the contract requirements (first-party audits), and also include provisions to have external audits sponsored by the management of the customer organization to verify that the supplier organization’s quality system meets the contract requirements (second party audits).

But when this kind of assurance arrangements become a common practice throughout the economy, the two-party, individual contract approach becomes burdensome. There develops a situation where every organization in the supply chain is subject to periodic management system audits by many customers and in the same time is subjected by many of its sub-suppliers to such audits. There is a lot of redundant effort throughout the supply chain because every organization is audited multiple times for essentially the same requirements, and the audits becomes a remarkable cost element for both the auditor organizations and audit organizations. The development of quality system certification/registration should be in direction to reduce the redundant effort of these multiple audits. Thus, development was in direction of standardization of quality system, where a third-party organization, which is called a “certification body” conducts a formal audit of a supplier organization to assess conformance to the appropriate quality system standard.

If the supplier organization is judged to be in complete conformance, the third party issues a certificate to the supplying organization and registers the organization’s quality system in a register. The terms “certification” and “registration” have the same marketplace meaning because they are two successive steps denoting successful completion of the same process. To maintain its registered status, the supplier organization must pass periodic surveillance audits by the registrar, which may be less extensive than the full audit. In the world today, there are a lot of certification bodies. Their services are valued by the supplier organizations they



register, and by the customer organizations of the supplier organizations, because the registration service adds value in the supply chain. It is critical that the certification bodies do their work competently and objectively and that all of them meet standard requirements for their business activities.[1]

## 2.4. Quality

There are many meanings of the word “quality,” but two of them are very important [1]:

1 - “Quality” means those features of products which meet customer needs and thereby provide customer satisfaction. In this sense, the meaning of quality is oriented to income. The purpose of such higher quality is to provide greater customer satisfaction and, one hopes, to increase income. However, providing more and/or better quality features usually requires an investment and hence usually involves increases in costs. Higher quality in this sense usually “costs more.”

2 - “Quality” means freedom from deficiencies—freedom from errors that require doing work over again (rework) or that result in field failures, customer dissatisfaction, customer claims, and so on. In this sense, the meaning of quality is oriented to costs, and higher quality usually “costs less.”

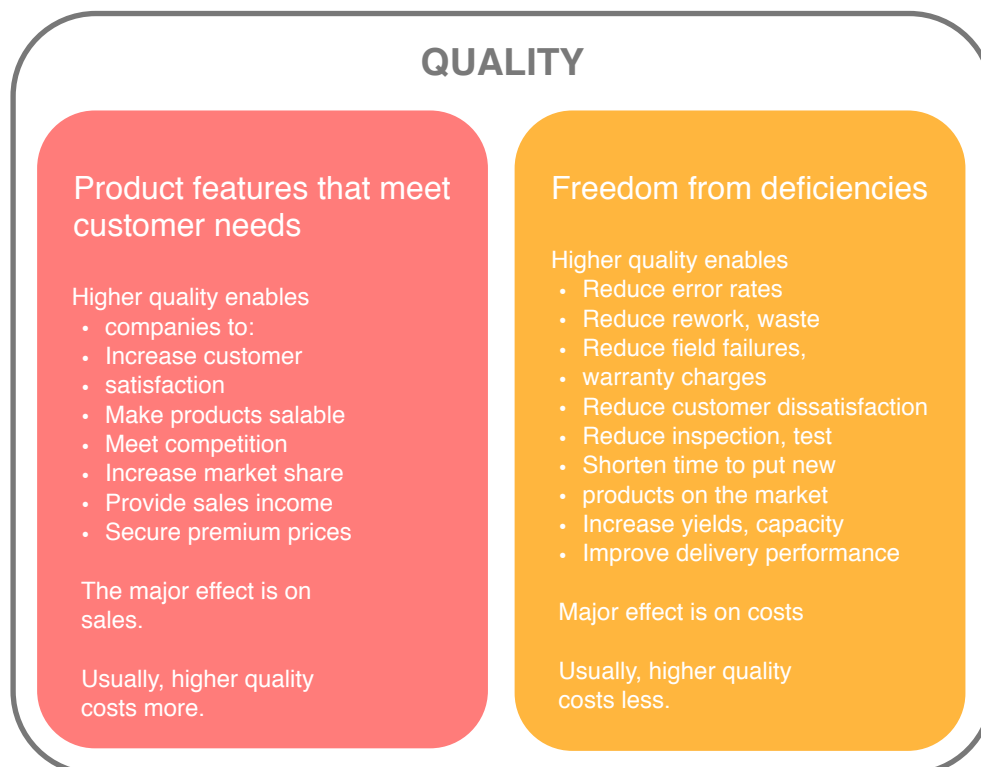


Figure 2.3. The meanings of quality

### ***2.4.1. Quality goals***

To control, assure, and improve quality you need to focus on certain goals. Let's call them the quality goals. Here are some key actions from which specific goals may be derived [a]:

- Establish your customer needs.
- Design products and services with features that reflect customer needs.
- Build products and services so as to reproduce faithfully the design that meets the customer needs.
- Verify before delivery that your products and services possess the features required to meet the customer needs.
- Prevent supplying products and services that possess features that dissatisfy customers.
- Discover and eliminate undesirable features in products and services even if they possess the requisite features.
- Find less expensive solutions to customer needs because products and services that satisfy these needs may be too expensive.
- Make your operations more efficient and effective so as to reduce costs, because products and services that satisfy customer needs may cost more to produce than the customer is prepared to pay.
- Discover what will delight your customer and provide it. (Regardless of satisfying customer needs your competitor may have provided products with features that give greater satisfaction!)
- Establish and maintain a management system that enables you to achieve these goals reliably, repeatedly, and economically.

### ***2.4.2. Quality Control***

The anatomy of quality assurance is very similar to quality control, each evaluates actual quality and compares actual quality with the quality goal. What differs is the prime purpose to be served. Under quality control, the prime purpose is to serve those who are directly responsible for conducting operations. Under quality assurance, the prime purpose is to serve those who are not directly responsible for conducting operations but who have a need to know and to be assured that all is well.

Quality control is a universal managerial process for conducting operations so as to provide stability. To maintain stability, the quality control process evaluates actual performance, compares actual performance to goals, and takes action on the difference. Quality control is one of the three basic managerial processes through which quality can be managed (the others are quality planning and quality improvement).[1]

The methodologies of Quality Control are built around various concepts such as the feedback loop, process capability, self-control, etc.

Quality control takes place by use of the feedback loop. The feedback loop is a universal and it is fundamental to any problem in quality control. It applies to all types of operations, whether in service industries or manufacturing industries, and also it applies to every levels in the hierarchy, from the chief executive officer to the work force. There are many ways of dividing the feedback loop into elements and steps. The most popular one is the so-called PDCA cycle (Figure 2.3.). In this example the feedback loop is divided into four steps labeled Plan, Do, Check, and Act.

These steps correspond roughly to the six steps discussed previously[1]:

- ▶ “Plan” includes choosing control subjects and setting goals.
- ▶ “Do” includes running the process.
- ▶ “Check” includes sensing and umpiring.
- ▶ “Act” includes stimulating the actuator to take corrective action.



Figure 2.4. PDCA Cycle loop

Flow Diagrams - For many products, the anatomy of the producing process is a sequential series of steps, where each performing a specific task. The steps may include those within the external supplier chain as well as those taken during marketing, use, and customer service.

Process Capability - One of the most important concepts in the quality planning process is process capability. Process capability relates to the effectiveness of the process in meeting customer needs.[1]

### ***2.4.3. Quality Control Manual***

A great deal of quality planning is done through “procedures” which are really repetitive-use plans. Such procedures are thought out, written out, and approved formally. Once published, they become the authorized ways of conducting the company’s affairs. It is quite common for the procedures relating to managing for quality to be published collectively in a “quality manual”.[1]

The quality manual of a company contain a core content which is quite similar from company to company. Relative to quality control, this core content includes procedures for[1]:

- ▶ Application of the feedback loop to process and product control
- ▶ Ensuring that operating processes are capable of meeting the quality goals
- ▶ Maintenance of facilities and calibration of measuring instruments
- ▶ Relations with suppliers on quality matters
- ▶ Collection and analysis of the data required for the quality information system
- ▶ Training the personnel to carry out the provisions of the manual
- ▶ Audit to ensure adherence to procedures

## **2.5. Quality Assurance Process**

The ISO definition states that quality assurance is all those planned and systematic actions necessary to provide adequate confidence that an entity will fulfill requirements for quality. Both customers and managers have a need for quality assurance as they are not in a position to oversee operations for themselves. They need to place trust in the producing operations, thus avoiding constant intervention.

Customers and managers need:

- Knowledge of what is to be supplied.
- Knowledge of how the product or service is intended to be supplied.
- Knowledge that the declared intentions will satisfy customer requirements.
- Knowledge that the declared intentions are actually being followed.
- Knowledge that the products and services meet your requirements.

You can gain an assurance of quality by testing the product/service against prescribed standards to establish its capability to meet them. However, this only gives confidence in the specific product or service purchased and not in its continuity or consistency during subsequent supply. Another way is to assess the organization that supplies the products/services against prescribed standards to establish its capability to produce products of a certain standard. This approach may provide assurance of continuity and consistency of supply. Quality assurance activities do not control quality, they establish the extent to which quality will be, is being, or has been controlled. All quality assurance activities are post-event activities and off-line and serve to build confidence in results, in claims, in predictions, etc.

Assurance is not an action but a result. It results from obtaining reliable information that testifies the accuracy or validity of some event or product.

Assurance of quality can be gained by the following steps (illustrated diagrammatically in Figure 2.6)[9]:

- Acquire the documents that declare the organization's plans for achieving quality.
- Produce a plan that defines how an assurance of quality will be obtained.
- Organize the resources to implement the plans for quality assurance.
- Establish whether the organization's proposed product or service possesses characteristics which will satisfy customer needs.
- Assess operations, products, and services of the organization and determine where and what the quality risks are.
- Establish whether the organization's plans make adequate provision for the control, elimination, or reduction of the identified risks.
- Determine the extent to which the organization's plans are being implemented and risks contained.
- Establish whether the product or service being supplied has the prescribed characteristics.

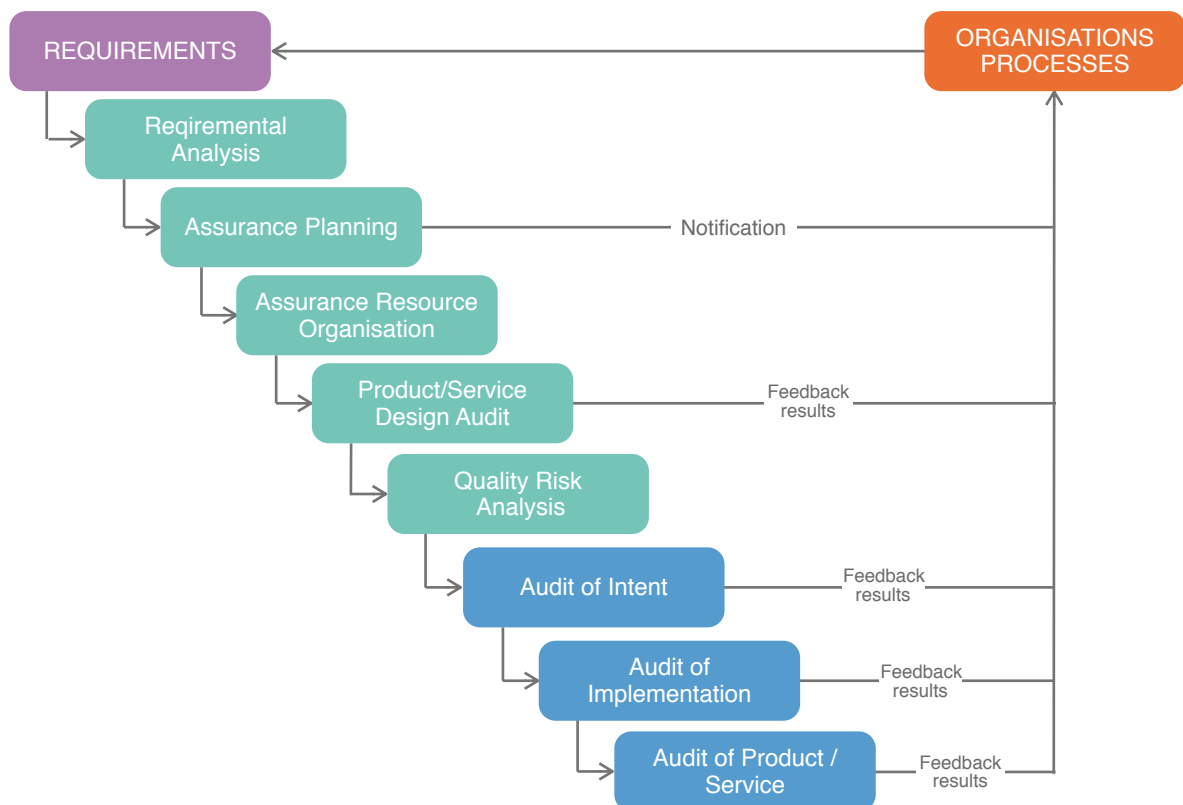


Figure 2.5 Quality assurance process [9]

In judging the adequacy of provisions you will need to apply the relevant standards, legislation, codes of practice, and other agreed measures for the type of operation, application, and business. These activities are quality assurance activities and may be subdivided into design assurance, procurement assurance, manufacturing assurance, etc. Auditing, planning, analysis, inspection, and test are some of the techniques that may be used.

### **3. CERTIFICATION PROCES IN MARINE SUPPLY INDUSTRY**

#### **3.1 Introduction**

The Marine sector is defined by its market, namely any industry that is involved in the supply chain of Marine related products and activities. This consists of those companies involved in all forms of marine manufacturing/construction, engineering and consultancy, as well as the design and manufacture of process and control equipment used in the marine industry such as navigation, communication and safety equipment. The Marine supplies industry serves different end product related markets as providers of material, components, equipment, systems and many different kinds of subcontracted work and services. The major markets and customers can be identified as follows[15]:

- New-building of merchant ships and offshore ships (shipyards, boatyards and shipping companies)
- Ship repair and conversion of merchant ships (shipyards, boatyards and shipping companies)
- Retrofitting - a special conversion market for ships following new regulations (shipyards, boatyards and shipping companies)
- Offshore platforms, jack-ups etc. for oil and gas (offshore and shipyards, oil and gas companies/operators)
- Offshore facilities, plants for offshore wind applications (offshore wind operators and wind farm developers)
- Naval shipbuilding, maintenance and repair (shipyards and governments)
- Boatbuilding (boatyards, shipyards)
- Other marine and maritime markets, e.g. underwater services, traffic and environmental surveillance, safety and security markets, harbor technologies, shipyard equipment,
- special polar markets

The marine supplies industry is a comparably fragmented industry. On the one hand, companies can be identified which are major players in their technological fields of systems

and components. These are more specifically marine equipment and systems manufacturers which serve different marine markets and acting internationally, nationally or cross border regionally. Depending on their level of export, they may depend more on the development of the international markets or the markets in the narrower vicinity (country or region).

Further the shipbuilding and offshore system and equipment supplies industry can be divided into the following types of companies[15]:

- Global (maritime) market leaders for one or more technological sub-sectors which basically serve the maritime and offshore market.
- Global technological specialist companies with significant maritime revenue shares, but also significant supplies to other industrial sectors.
- Maritime specialist companies that serve essentially only the maritime and offshore market in Europe as well as worldwide. These companies operate either only one or several maritime sub-markets.
- Industrial generalists with lower maritime revenue shares but still significant global maritime market shares.

### ***3.1.1 Supply Chain Structure***

In the marine supply chain we can distinguish between marine suppliers and their subcontractors. Marine suppliers are characterized by the fact that they develop functions or entire, complex systems according to their own patents and techniques and they operate by respecting the specifications and terms of references defined by the customer for complete products or subassemblies. Marine suppliers can be subdivided in system suppliers, component suppliers and material suppliers.

Marine subcontracting exists whenever the customer participates in the conception of the product, even partially providing specifications to the manufacturer ranging from detailed technical plans to imprecise specifications.

Marine subcontractors can be subdivided in those offering services for manufacturing and assembly and those offering services in the areas of engineering, design and consulting.

Further labour services are included in the purchase of material, systems and components which cannot be identified separately.



In the supply chain pyramid (figure 3.1) two forms of co-operation, in term of supplier and subcontractor, are defined: horizontal and vertical.

Vertical co-operation exists because of the high complexity and fragmentation of the products and sub-products. Horizontal cooperation between shipyards (or comparable manufacturers of turn-key modules) exists for capacity or delivery reasons.

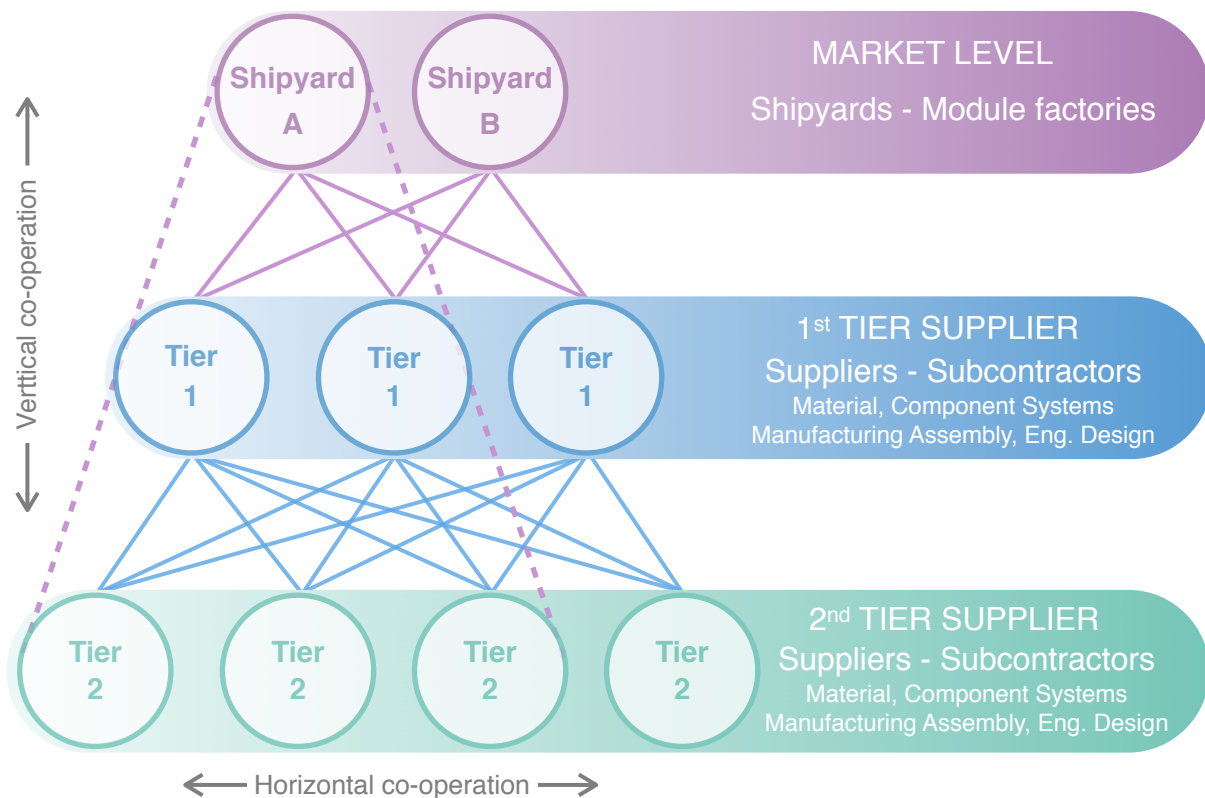


Figure 3.1. Horizontal and vertical co-operation between shipyards and suppliers

How marine supply industry appearing as a very heterogeneous industry, it must be stated that there is no formal structure available which classifies marine supply into consecrated categories. All parties which try to find a suitable categorization find different solutions which serve more or less their own interests.

## 3.2. Classification Societies

### 3.2.1. *Historic Role of Classification Societies*

In the 17th and 18th century the classification societies have been appeared out of the need for insurers to get information about a ship. Before that it relies on rumors in bars and inns near ports to establish an opinion about a ship's condition. Ship-owners needed help to ensure the technical seaworthiness, where the insurers want the guarantee that the ships are sea-worthy.

Therefore, initially marine insurers, based at Lloyd's coffee house in London, developed a system for the independent technical assessment of the ships presented to them for insurance cover. In 1760 a Committee was formed for this purpose, the earliest existing result of their initiative being Lloyd's Register Book.[4] That was actually also the year of the establishment of the first classification society, which was first named "the Register's Society". It was renamed later on to Lloyd's Register (LR) as a tribute to Edward Lloyd who was the owner of the Lloyd's coffee house.

This concept of the classification slowly spread to other countries and insurance markets.

Bureau Veritas (BV) founded in Antwerp in 1828 (after moving to Paris in 1832), American Bureau of Shipping (ABS) formed in 1862, Registro Italiano Navale (RINA) in 1861, Det Norske Verities (DNV) in 1864, Germanischer Lloyd (GL) in 1867, did follow Lloyd's Register to name a view.

The business for the classification society had the purpose of controlling the ways of construction and maintenance of the ships on behalf of the underwriters (insurers). Ship owners were now interested in fixed "ratings" to be assigned to their vessels with a validation of a certain time. At the first time of classification society, it started with classification according to the condition of their hull and equipment. The classification society who indicate condition of the hull was classified by using the capital letters: A, E, I, O or U, according to the excellence of its construction and equipment was classified by using the capital letters: G (good), M (middling), or B (bad). The letters of equipment: G, M and B, were replaced after with numbers from 1 to 3. In that time the symbols reflected the class of ships according to the degree of application of their rules in the condition of ships. [8]

The owners were able to present the ratings to insurers and cargo owners whenever demanded and did not have to undertake a survey every time they needed to prove the ship's state.[8]

The appearance of the term “ratings” forced the societies to introduce a more uniform approach, such as an unified ship construction code. Thus, the first Lloyd Register's rules were published in 1835 for wooden ships, and those for Iron ships, in 1855. These rules were more favorable to marine mechanics than the former ship-masters in the recruitment of surveyors.

Now shipyards began to be considered as customers of Classification societies due to delivery of vessels with given ratings. These rules are gradually transformed to be on obligatory reference for assessing ship safety, since it was considered to be a guarantee of assessment that vessels were in compliance with their requirements. The initially labeling by the letters no longer indicate classification of ships. The symbols given by classification societies indicate that ships are in their class, and the term ‘classification’ means the compliance with their standards, thus, a ship is either “in” or “out” of “class”.

During the second half of the 19th century regulation of safety at sea were gradually taken over by maritime authorities, since they were genuinely the matters concerned with states or international communities. Due to the complexities of surveying ships, the authorities needed to empower the societies to inspect vessels for safety of shipping.

In other words, classification societies were born initially out of the need for insurers to get information about a ship, and to be able to calculate realistic premiums for the insurance of it and its cargo, whereas in recent years their services become much more complex and have been broadened as public entities based on the agreements of the flag state, etc. And, as technologies have been continuously developed throughout the shipping history, class societies had to adapt their rules to new technologies.

### ***3.2.2. Present Role of Classification Societies***

Today's classification societies certify the ships in accordance with international conventions and classify the ships in accordance to their own rules. They also do assistance to the maritime industry and regulatory bodies as regards maritime safety and pollution prevention. Their objective is to verify the structural strength and integrity of essential parts of the ship's hull and its appendages, and the reliability and function of the propulsion and steering

systems, power generation and other features and auxiliary systems which have been built into the ship in order to maintain essential services on board. [4]

A vessel that has been designed and built to the appropriate Rules of a Society may apply for a certificate of classification from that Society. However, such a certificate does not imply, and should not be construed as, a warranty of safety, fitness for purpose or seaworthiness of the ship. [4] The main purposes of their certificates is to be used by the owner to gain trust from a multitude of “third parties”. [8] The shipowner is only one who has the overall responsibility for the safety and integrity of a vessel, including the manner in which it is operated and maintained.

Classification Rules are developed to establish standards for the structural strength of the ship’s hull and its appendages, and the suitability of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship to assist in its operation. In developing its Rules, a Classification Society typically relies on empirical experience gained from classing a wide variety of ship types over many years, coupled with appropriate research that contributes towards the on-going development of relevant, advanced technical requirements. In establishing its Rules, each Classification Society may draw upon the advice and review of members of the industry and academia who are considered to have relevant knowledge or experience. [4]

The classifications are only system that provides shipowners, shipbuilders, charterers, insurers and financiers with a high level technical service that covers all from design and construction to the end of their operational life. Another aspect of the classification rules development is their ability to address swiftly the new issues challenged by technological steps made by the industry, where the response should be swift enough, in order to serve the maritime community timely.

In short, today class societies are very important actor of the maritime community who develop and apply sensible and technically relevant prescriptions, provide software tools to support the implementation of the rules and enable direct analyses whenever useful or necessary, and bring evolution to these rules and software tools to match the technological innovations timely.

When the governments began the process of formulating marine safety regulations, first independently and later under the auspices of the IMO, it was considered unnecessary to provide detailed requirements as these were covered by classification, ranging from hull

structure to essential engineering and electrical systems.[9] Thus, classification societies certify the ships in accordance with international conventions (IMO convention) - statutory certificate and classify the ships in accordance to their own rules - class certificate. Relation between Class certificate and Statutory certificate is presented in Figure 3.2.

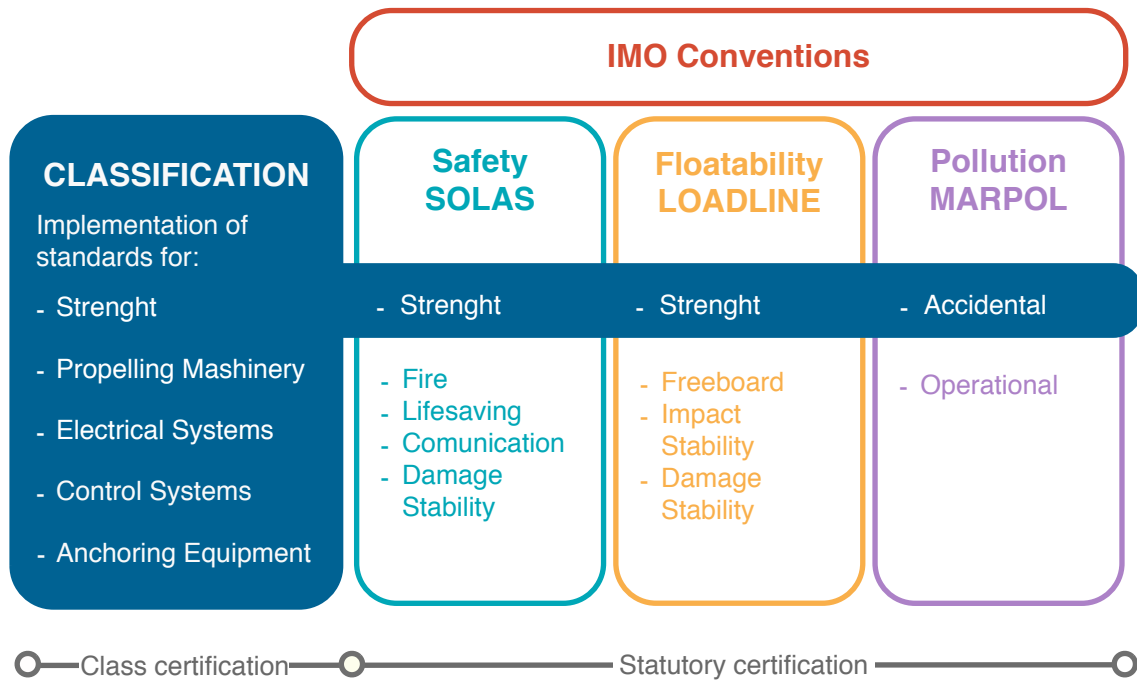


Figure 3.2. The Relation between Class and Statutory certification

Shipowners, shipbuilders, port states, flag states, charterers, P&I Clubs, and notably, classification societies have traditionally worked closely to enhance safety on the high seas. Progressively, however, classification societies have become the primary safety group connecting all the maritime entities.

### **3.3. IACS - International Association of Classification Societies**

The idea of establishing such an organization was associated with the Load Line Convention of 1930. The Convention recommended collaboration between classification societies to secure “as much as uniformity as possible in the application of the standards of strength upon which freeboard is based. [4]

In 1939, RINA hosted the first conference of major societies ABS, BV, DNV, GL, LR and NK, which agreed on further cooperation between the societies.

In 1955, the second major class society conference led to the creation of working parties on specific topics and finally the IACS was formed in 1968 by seven leading classification societies, ABS, BV, DNV, GL, LR, NK and RINA.

In 1969, IACS was given consultative status with IMO. It remains the only nongovernmental organization with Observer status which is able to develop and apply rules.[4]

Individual class standards were harmonized by agreeing on uniform technical requirements which have increasingly become the underlying technical fabric of maritime safety.[9]

Common Rules for hull structures of oil tankers and bulk carriers were adopted in December 2005. This was a most ambitious and expensive project and one of the most important single steps in the development of maritime rules that IACS has ever been involved with.[4]

Since its establishment IACS has been working towards three main objectives:

- To promote the improvement of the standards of safety at sea;
- To consult and collaborate with national/international maritime organizations
- To maintain close cooperation with the world maritime industries.

In 1991, IACS launched its Quality Certification Scheme (QSCS) to ensure integrity and increase standards in ship’s classification service. The scheme sets and monitors rigorous standards and has been strengthened further to invoke standards more rigorous than the requirements of ISO 9001.[9] Compliance with the IACS Quality System Certification Scheme (QSCS) is mandatory for IACS Membership.[4]

With its Members and Associates, IACS has become a crucial partner in the international maritime community in terms of their combined and unique level of classification knowledge and experience in contributing to maritime safety and its regulatory regime.

### **3.4 Principle Certification Process in Marine Supplies Industry**

The principle certification requirements defined by the IACS include two main requirements that can be extracted and implied how product manufacturers need to comply in general terms against specific classification rules. Classification process for key component supplier, manufacturer consists of:

- Design certification - a technical review of the design and related documents for a product verify compliance with the applicable Rules and
- Materials and component certification - attendance by a Classification Society surveyor (surveyor witnessing) at the relevant production facilities that produce the product to verify that the component conforms to the applicable Rule requirements.

#### ***3.4.1 Design Certification Models***

One of the most used model is “case by case” design certification model. The next more generic model is “design type certification”, which is in some classification societies named as “design appraisal”.

As an alternative scheme to the design approval “case by case” for the standard design of products produced in series there is Type Approval (TA) scheme. The type approval scheme include: design assessment, type testing and approval of the company's Production Quality Assurance for some cases (e.g. for EU RO MR TA)

#### ***3.4.2 Materials and Component Certification Models***

Materials, Component and Equipment certification is the second part of certification process. The purpose of this process is to ensure the quality and traceability of used materials and components and assembled equipment (complex marine units).

The material certification process based of the application of product specific rules and procedures maintained and regular updated by the Classification societies. The material certification process requires specific “samples” and “test reports” performed and documented by the contracted class society or other defined authority as specified by the material specification. Certified components and materials can be traced by unique item codes or by item serialization. Materials are serialized “by lot” and components requiring certificate “by

unit” or “by lot”. Most used material certification is “case by case” certification using direct inspection at the manufacturers work , however, there is an option to certify material under Quality Assurance Schemes which will allow manufacturer to do self-testing of the materials without presence of surveyor.

Product certification is the top level certification that links the product to the actual application (e.g. ship). Type approved components or products must always be still documented against the application and classification societies will review that the type approvals are compliant within the application and usage of product in it. The product certification process usually includes system and assembly level testing. The classification society inspects onsite that the manufactured product and certified documentation is according the rules for specific application.

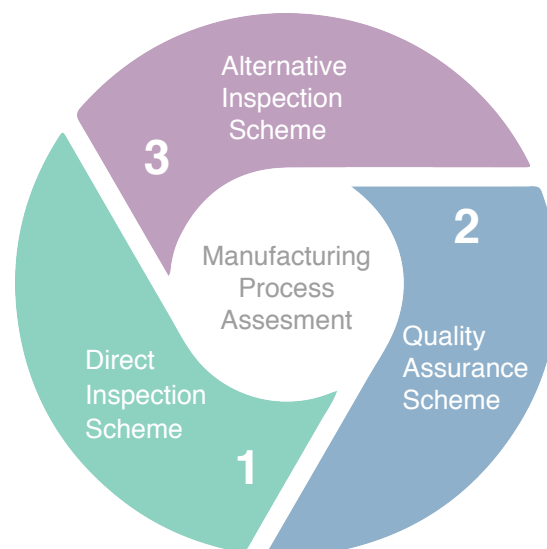


Figure 3.3 Manufacturing process assessment options

When product and documentation is according specific rules the surveyor will issue a final inspection certificate and this type of inspection is called “direct inspection”. Second option of inspection for manufacturing process, usually for products produced in series, is called “Quality scheme certification”. In Lloyd’s Register this approval model is called Quality Assurance Scheme for Machinery (QAM) in DNV this approval model is called Manufacturing Survey Arrangement (MSA). After obtaining this kind of certificate, manufacturer is able to do self-testing of the parts without presence of surveyor but aligned with an audit process of manufacturing processes and combined with the assessment of a functional QMS system. Another, third option of inspection of the manufacturing processes is



the combination of previous two option usually representing a kind of “Alternative option for approving manufacturing process” (Figure 3.3). Details about Alternative certification models are provided by IACS UR Z 26 [37].

### 3.4.3 Classification safety hierarchy of materials, equipment and components on a ship

The safety regime at sea is mature with well-established legislative processes, routines and practices for assuring safety through implementation. Classification is a part of the safety regime, and the scope of class involvement has evolved through empirical risk assessment over more than a century. A classification is today only involved when safety and reliability are at stake, and the involvement of classification increases as the safety criticality of the equipment, component or product increases. The hierarchy of class involvement is shown in the following figure (Figure 3.4).

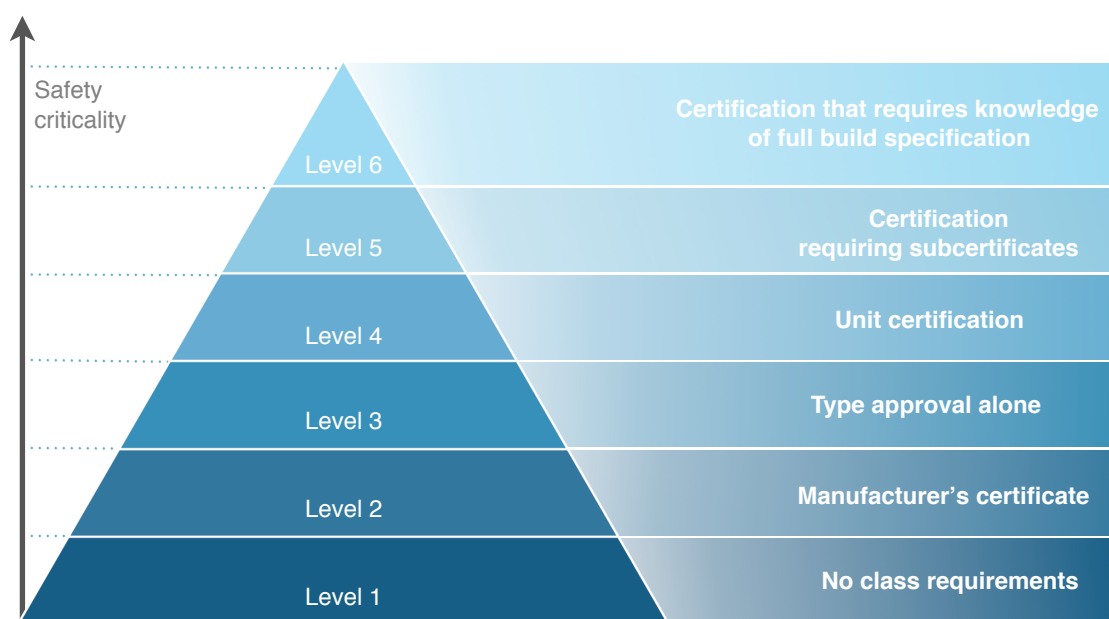


Figure 3.4 The hierarchy of safety levels [26]

**Level 1 - No class requirements.** For a big part of the equipment on board it is not required any type of class involvement or certification, simply because the equipment is non-safety critical or it is not part of safety critical systems, e.g. furniture and entertainment systems.

**Level 2, Manufacturer's certificate.** This level of the safety hierarchy is equipment where manufacturers' declarations of conformity are sufficient. This is very simple components e.g. small distribution boards, semi-conductor converters, sounding rods and condensers etc., and these pieces of equipment represent lower risk cases.

**Level 3, Type approval alone.** The equipment in level three is considered to have a low safety criticality e.g. electrical heating cables and sensors and similar such components.

For acceptance of this category a type approval certificate is sufficient. Type approval facilitates mass production since no individual or product-specific certificate is required.

**Level 4, Unit certification.** At this level, each individual product will be seen as clearly safety critical, thus, each manufactured unit has to be approved and the production and/or test of the specific unit must be witnessed. In this category there are very different components e.g. large electrical machines, pumps, propeller shafts and subcomponents of main and auxiliary diesel engines.

**Level 5, Certification requiring sub-certificates.** This level relates to more complex equipment and systems such as main engines, thrusters and podded thrusters. For these highly complex items typically built to meet ship specific requirements, equipment certificates are needed for sub-assemblies in addition to the main unit certificate.

**Level 6, Certification requires knowledge of full build specification.** The highest level of the safety hierarchy relates complete systems such as main propulsion systems or dynamic positioning systems, where is required deep knowledge about the specific build and operation of the ship, including many of the other on board systems.[26]

#### ***3.4.4. Marine Equipment Directive (MED)***

The European Commission, with the view to harmonize standards for the design, construction and acceptance procedure for the items of equipment referred to in SOLAS and MARPOL, has developed with the help of the industry and the member states, the Marine Equipment Directive (MED). This covers only defined equipment that required under International Conventions, carried and used on ships registered under the flag of a EU member state. The applicable standards and the products are explicitly listed in the directive and their Annexes and is mainly applicable to European Flagged ships. Under the procedures defined in the MED, once an approval has been obtained for the equipment referred to in the Directive by a single Notified Body (Classification Societies are one of the Notified Bodies), this approval will be acceptable in all other member states.

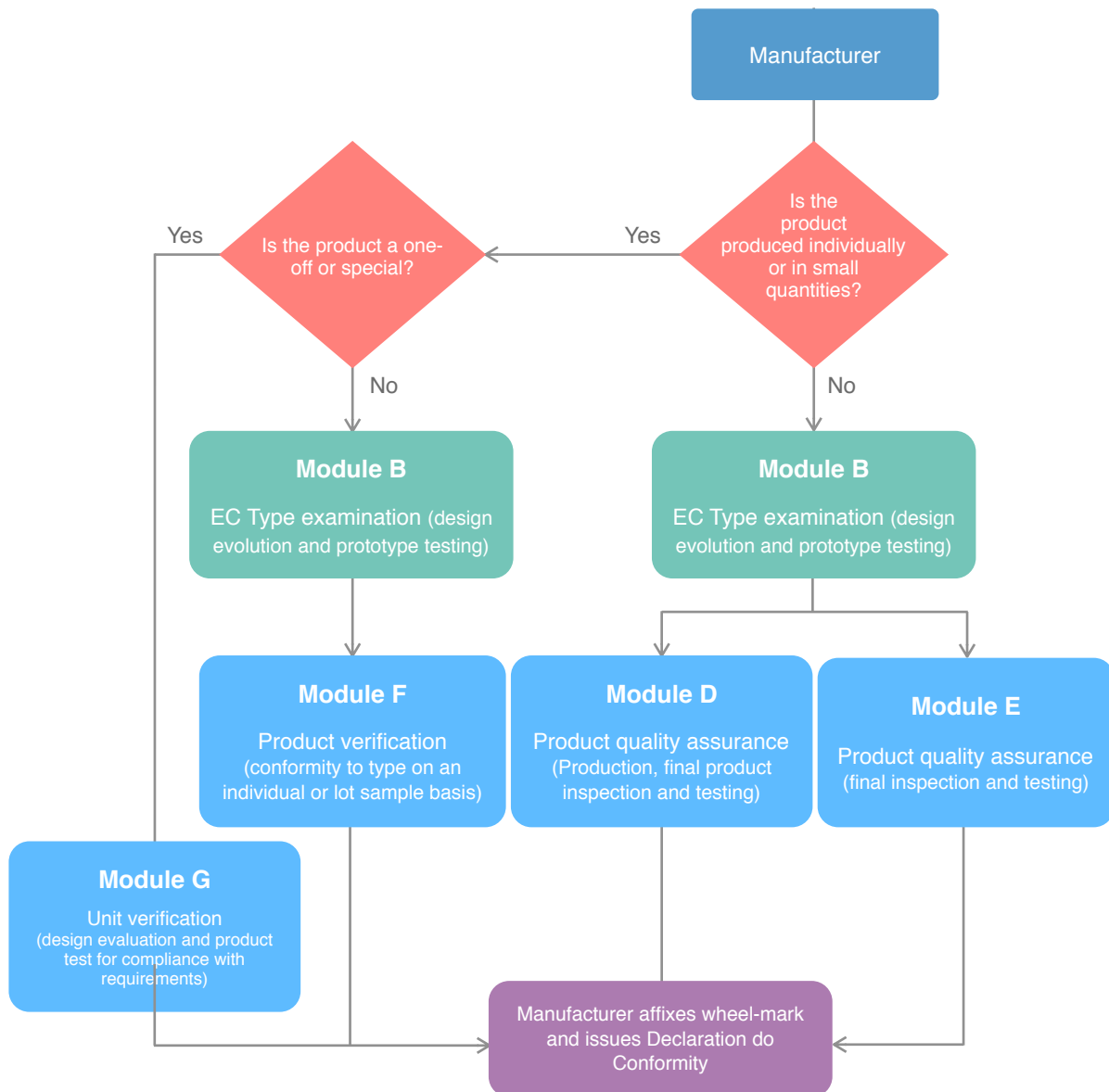


Figure 3.5. MED Scheme of certification process for different modules [27]

Under the MED have different modules (B, D, E, F, G) that cover different products, but first module B is design evolution and type testing (EC type examination) and in the majority of cases a Module B certificate is necessary and this must be used in combination with one of the other modules (D, E, or F), which are production modules. For the case of Modul G, no Module B is applicable since Module G requires that all prototype tests are conducted on every individual product. The MED scheme is presented in figure 3.5.

### 3.4.5 EU RO Mutual Recognition within ship classification

Recognized Organizations (RO) shall agree on the technical and procedural conditions under which they will mutually recognize the class certificates for materials, equipment and components based on equivalent standards. In line with the above-mentioned remits, the EU ROs have worked together in order to find ways to mutually recognize each other's class certificates for initially equipment and components which require Type Approval without compromising safety. This has been done by a systematic approach in harmonizing the technical and procedural conditions for the different certification/inspection requirements as laid down in the technical rules of the participating ROs. The EU ROs have chosen a process to develop common Technical Requirements (TRs), taking "the most demanding and rigorous standards" as a reference, for the equipment found appropriate for Mutual Recognition. Furthermore, the approach is well aligned with the change to methodologies applied by ROs in general and in relation to the IMO requirements.[6]

For critical systems, products with an EU MR Type Approval Certificate cannot be accepted under Mutual Recognition arrangements for serious safety reasons. Thus, the scope for Mutual Recognition has been limited to the group of equipment currently approved based on type approval certificates alone, described under Level 3 of the safety pyramid (figure 3.4). To support the process of deciding the criticality and safety impact the EO ROs using a simplified risk model developed for that purpose. Technical and procedural conditions for EU RO Mutual Recognition of Type Approval Certificates for equipment and components based on equivalent standards is presented in the following flow chart (figure 3.6).[26]

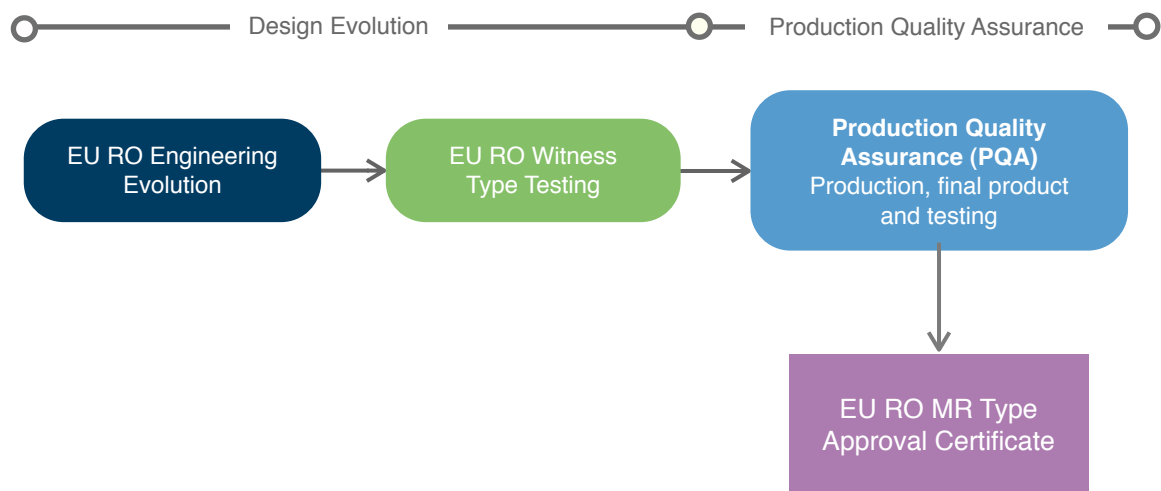


Figure 3.6. Flow chart for EU MR Type Approval process [26]

### **3.5 Lloyd's Register (LR) Certification Schemes**

Lloyd's Register certification is an impartial system representing product's conformance to the requirements of specific standards and/or LR rules, based on examination which might include:

Design review and product testing or testing of representative samples of the product and verification of satisfactory control of product. For some application the manufacturing process may need to be qualified before the products are certified, which results in a works approval being in place as a prerequisite for product certification.

There are three approval option of product certification[27]:

1. Works approval - approval of specific manufacturing location for producing materials by qualification of a defined manufacturing process which comprises manufacturing review and type testing.
2. Type approval - approval of product type for items of equipment and component, system and welding consumables which comprises as appropriate, design review, type testing and quality assurance
3. Product Certification (direct inspection or Quality Scheme application) - certification of produced items of materials component and equipment (MC&E) of specific items which allow items to be placed on-board of Classed vessels, which comprises design review, type testing and product testing and inspection where appropriate or defined in the rules.

#### ***3.5.1. Works Approval Certificate***

Works Approval involves qualification of a manufacturing process and assessment of a company's quality assurance practices to confirm capability to manufacture products to LR rules or national/international standards where applicable.[LR]

To obtain the certificate a company has to submit following information:

- Quality Management System
- Manufacturing controls
- Statistics of relevant products
- Inspection procedure and
- Test plan for the tests which are specified for the particular products

Following LR's review and agreement with the test plan the company commences the approval testing under survey and submit the results to LR for review and approval. If the results are found to be satisfactory a certificate of approval is issued to the company by LR.

Work approval certificate is valid for the three years.

### **3.5.2. LR Type Approval Certificate**

This category is the approval against requirements of agreed standard(s) and/or LR rules. In LR rules, there are some products for which LR requires the type approval process and a works or type approval certificate issued before they are accepted to LR class.

The main certificates of the type approval categories are following[27]:

1. Works Approval Certificate
2. LR Type Approval Certificate
3. MED Type Examination Certificate, Module B
4. EU MR Type Approval Certificate

The LR type approval does not remove the requirements for:

- Inspection and survey procedures required by the LR rules for MC&E intended for ship classed with LR
- Plan appraisal of a system that incorporates type approved MC&E as required by the LR rules

### **3.5.3. LR Product Certificate (Direct inspection and /or Quality Scheme (QA) Inspection)**

For Works and Type Approval, LR has to be fully satisfied that the manufacturer has a quality management system in place to ensure the conformity of the products during the various production stages. In case of an existing QA Scheme the place of manufacturing will be inspected by Lloyd's Register Auditors in order to check the efficiency of the established Quality Assurance system with frequently controls.

It is still the responsibility of the manufacturer for implementing and maintaining an efficient production quality control system to ensure conformity of the product, including the maintenance of quality records e.g. complaints, feedback, etc.

Under Product Certification, when material or components being certified for specific application (i.e. on-board a vessel or series of vessels), product testing is to verify the quality

of the item (or batch) and all testing and inspection required by the appropriate rules and regulations have been complied with.

This can be done applying a Quality Assurance Schemes (Material Quality Scheme - MQS and Quality Assurance Scheme for Machinery - QAM) enable part or full certification of products by the manufacturer without LR witnessing product testing & inspection. Flow chart of the certification processes are presented in the figure 3.7, 3.8, and table 3.1.

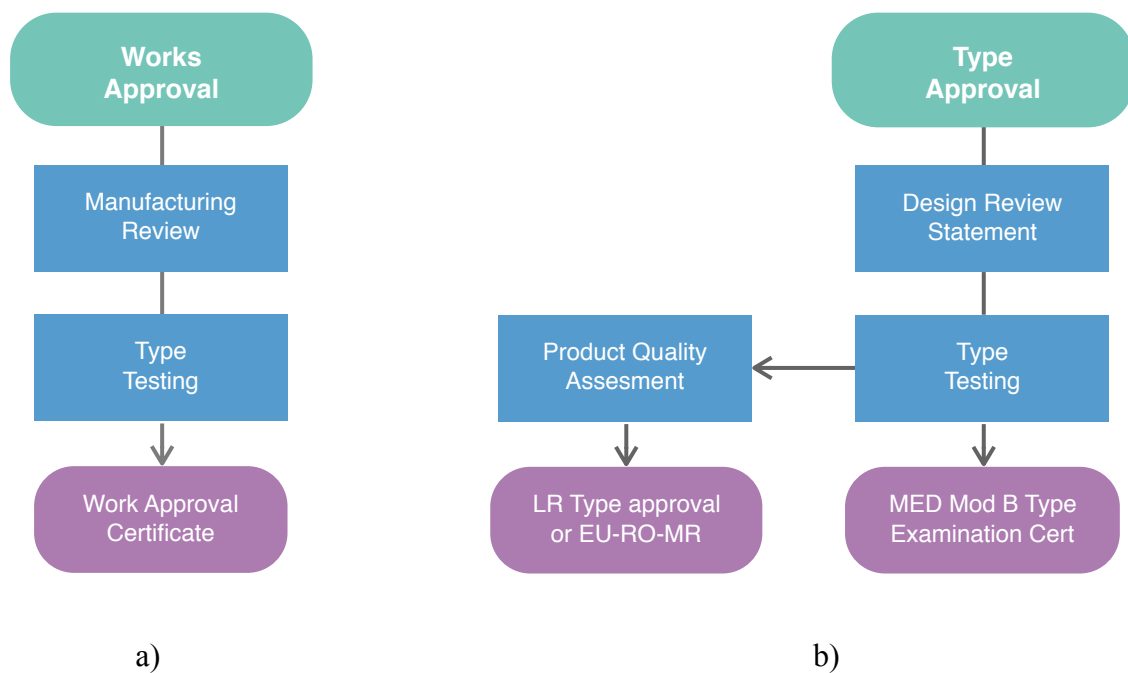


Figure 3.7. LR's certification options flow charts [27]  
a) Work Approval, b) Type Approval

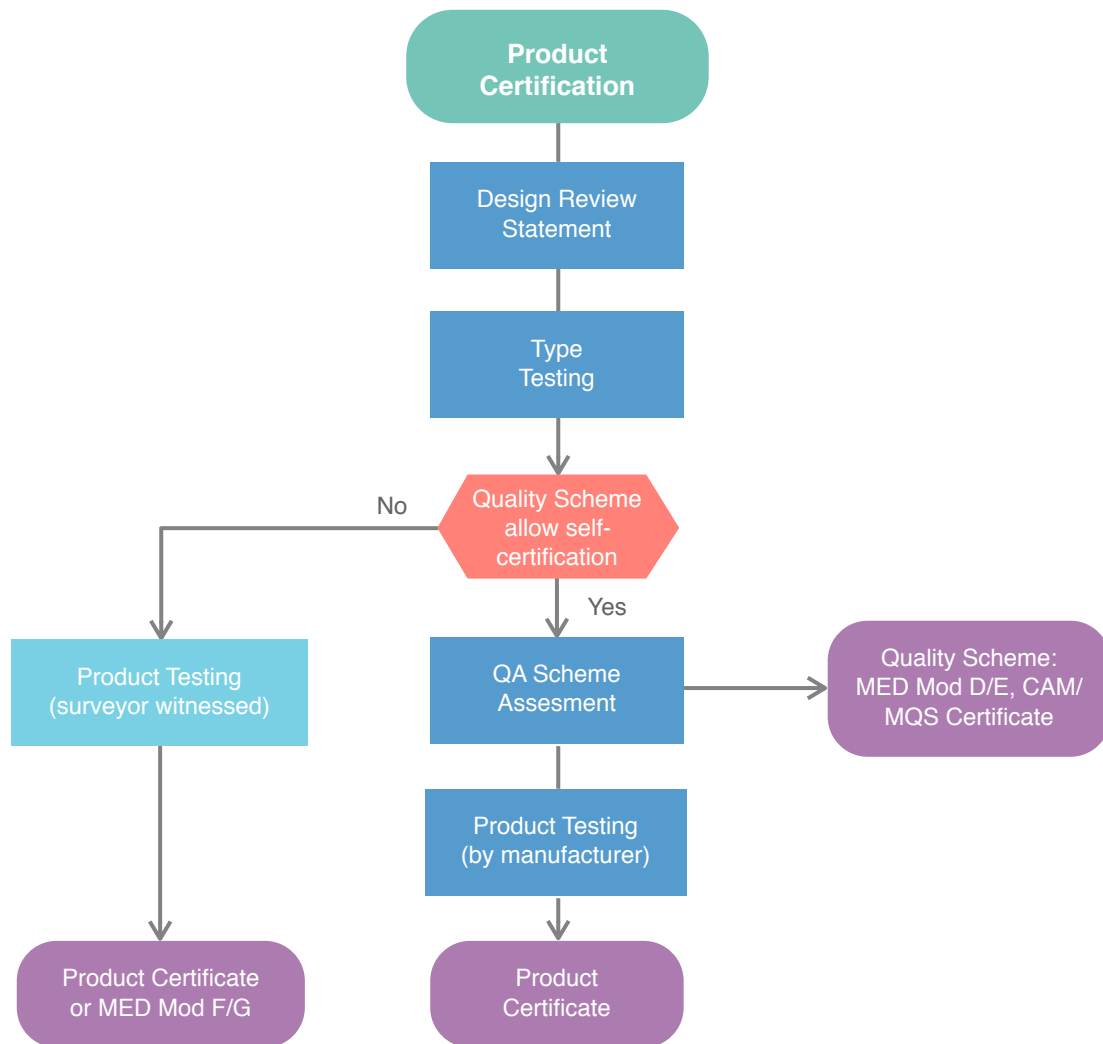


Figure 3.8. LR's certification options flow charts of Product Approval (Direct inspection and /or Quality Scheme - QA Inspection) [27]



Table 3.1. LR's certification options

Type of Certificate	Approval	Production
<p><b>Statutory Type Approval</b> (Such as fire protection, LSA and pollution equipment.)</p>	<p>Design review against applicable SOLAS or MARPOL requirements. Agree suitable testing and review test reports to confirm compliance. Certificate issued valid for 5 years.</p>	<p>Product certification is not required, but the producer is required to operate a QA system that is audited by a recognized Competent Authority.</p>
<p><b>Marine Equipment Directive</b> (Such as fire protection, LSA and pollution equipment.)</p>	<p>Design review against applicable SOLAS or MARPOL requirements. Agree suitable testing and review test reports to confirm compliance. Module B certificate issued valid for 5 years.</p>	<p>Individual batches are inspected and module F certificates issued.(self certification not allowed) Quality system assessed and Module D or E certificates issued. Production subject to audit</p>
<p><b>LR Type Approval</b> (Such as diesel engines, valves, flexible hoses, circuit breakers and programmable equipment.)</p>	<p>Design review against agreed standard/ specification including any applicable LR Rule requirements. Witness agreed test program, which also includes performance testing. Assess manufacturing facilities/ arrangements. Type Approval certificate is valid for 5 years.</p>	<p>Production/testing subject to inspection where required by the LR Rules. LR Quality Scheme can be used where inspections required by the LR Rules during the course of manufacture are delegated to the manufacturer and subject to regular audit by LR.</p>
<p><b>Design Appraisal</b> (For components not covered by LR Type Approval, but the LR Rules require to be of an approved type.)</p>	<p>Design review of component for compliance with applicable LR Rules, including type tests, if required.</p>	<p>Production/testing subject to inspection where required by the LR Rules. LR Quality Scheme can be used where inspections required by the LR Rules during the course of manufacture are delegated to the manufacturer and subject to regular audit by LR.</p>
<p><b>Approval of Manufacturing Process</b> (Such as steel plate and sections)</p>	<p>Initial approval given subject to specific inspection and testing in accordance with LR procedures.</p>	<p>Production/testing subject to inspection where required by the LR Rules. LR Quality Scheme can be used where inspections required by the LR Rules during the course of manufacture are delegated to the manufacturer and subject to regular audit by LR.</p>
<p><b>Other Products</b> (Such as welding consumables and shop primers.)</p>	<p>Initial approval given subject to specific inspection and testing in accordance with LR procedures.</p>	<p>Production/testing subject to inspection where required by the LR Rules. Welding consumable are to be tested annually.</p>

### 3.5.4. Certification of Steering Gear

Certification proces of steering gear model: Triton 800-45, produced by company HATLAPA, is presented below (figure 3.9).

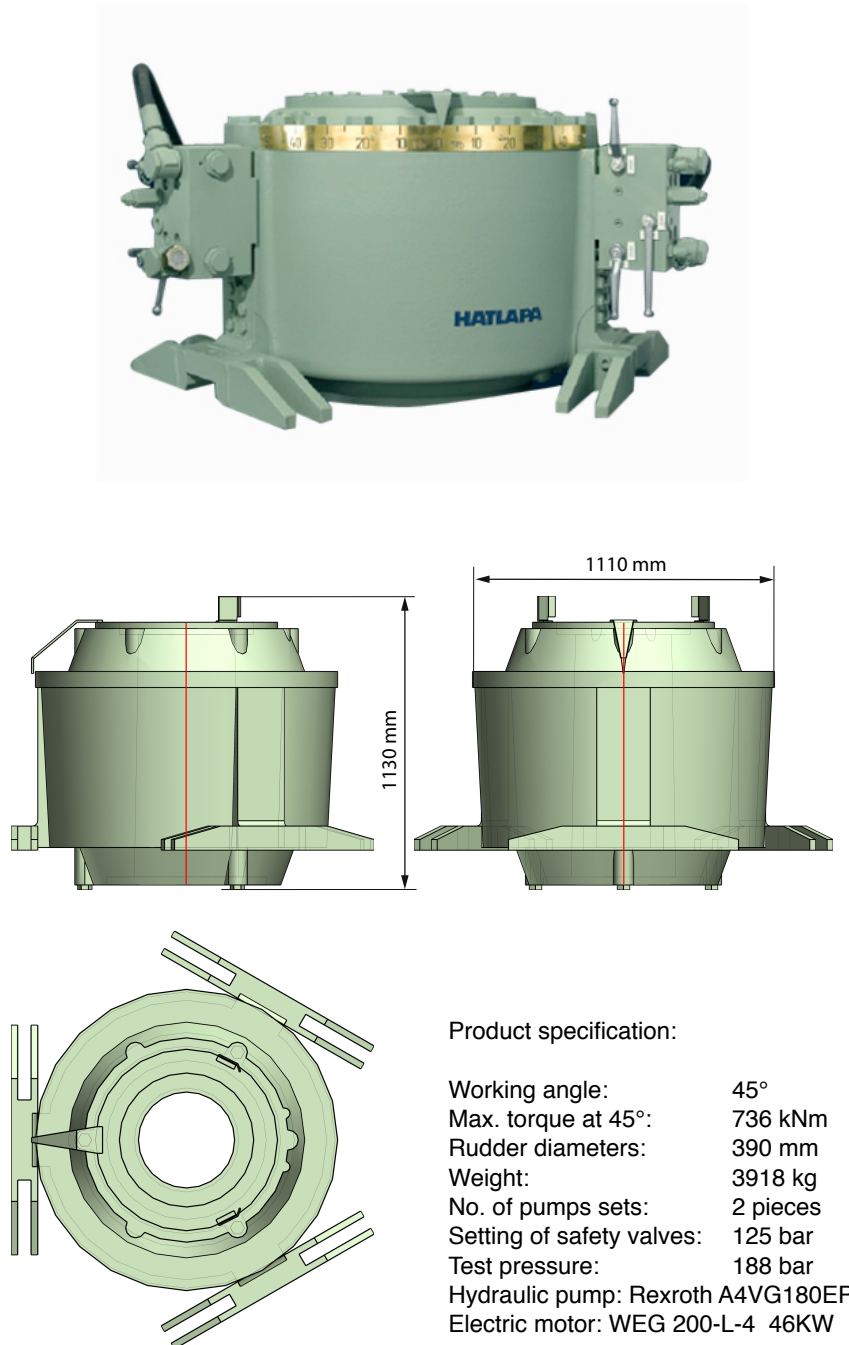


Figure 3.9. Rotary Vane TRITON 800-45 [34]

The certification proces is explained for two different scheme: direct surveys and quality assurance scheme for machinery (QAM) based on Lloyd's Register rules.

First way is direct surveys (traditional way) based on Lloyd’s Register rules (Figure 3.10). Direct surveys is carried out for each individual product.

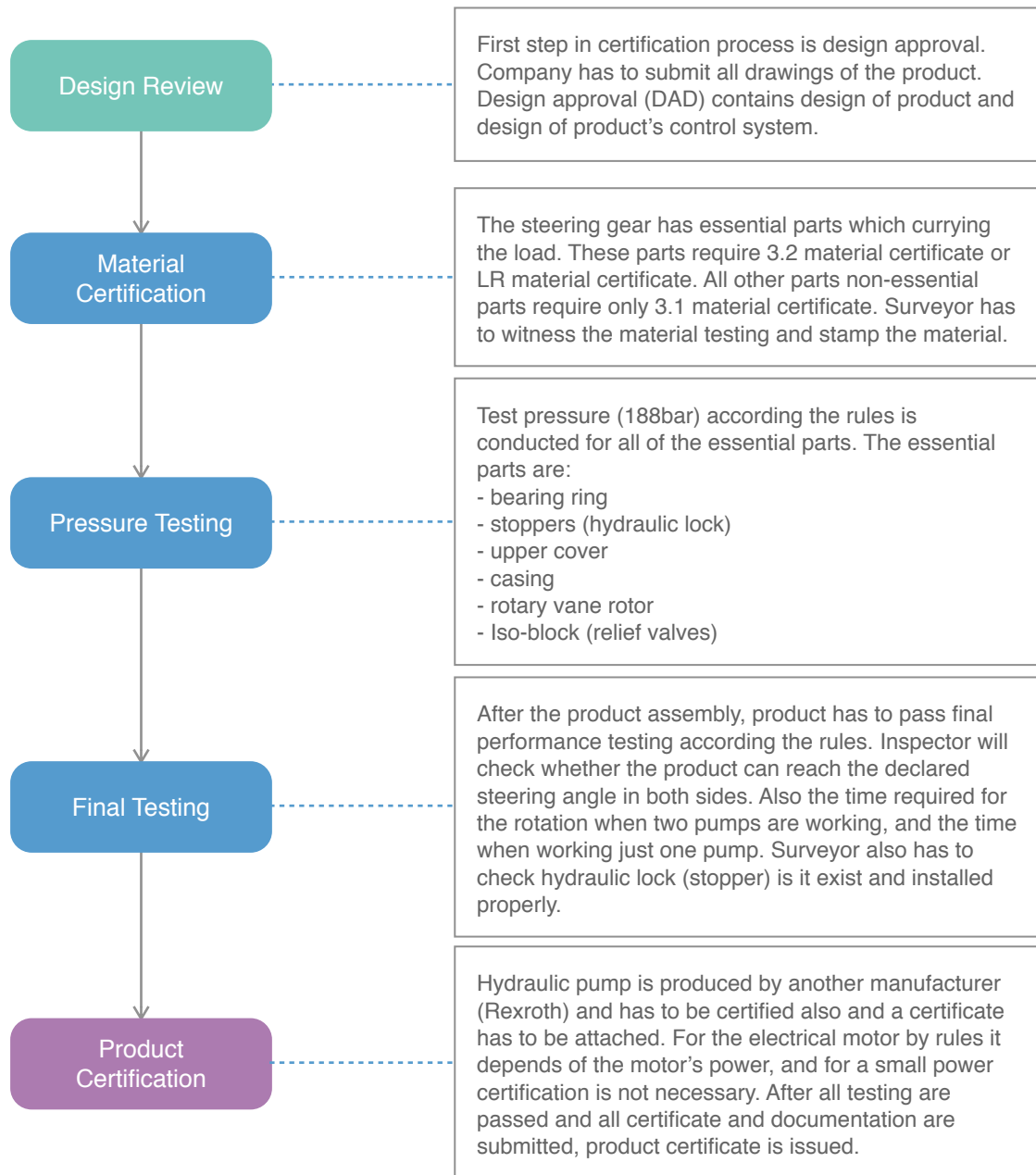


Figure 3.10. Certification process of the steering gear (Rotary Vane TRITON 800-45), direct surveys (case-by-case)

Below the product certification process of the steering gear (Figure 3.11.) is described in SIPOC (Supplier – Input – Process – Output – Customer) process model for direct surveys.

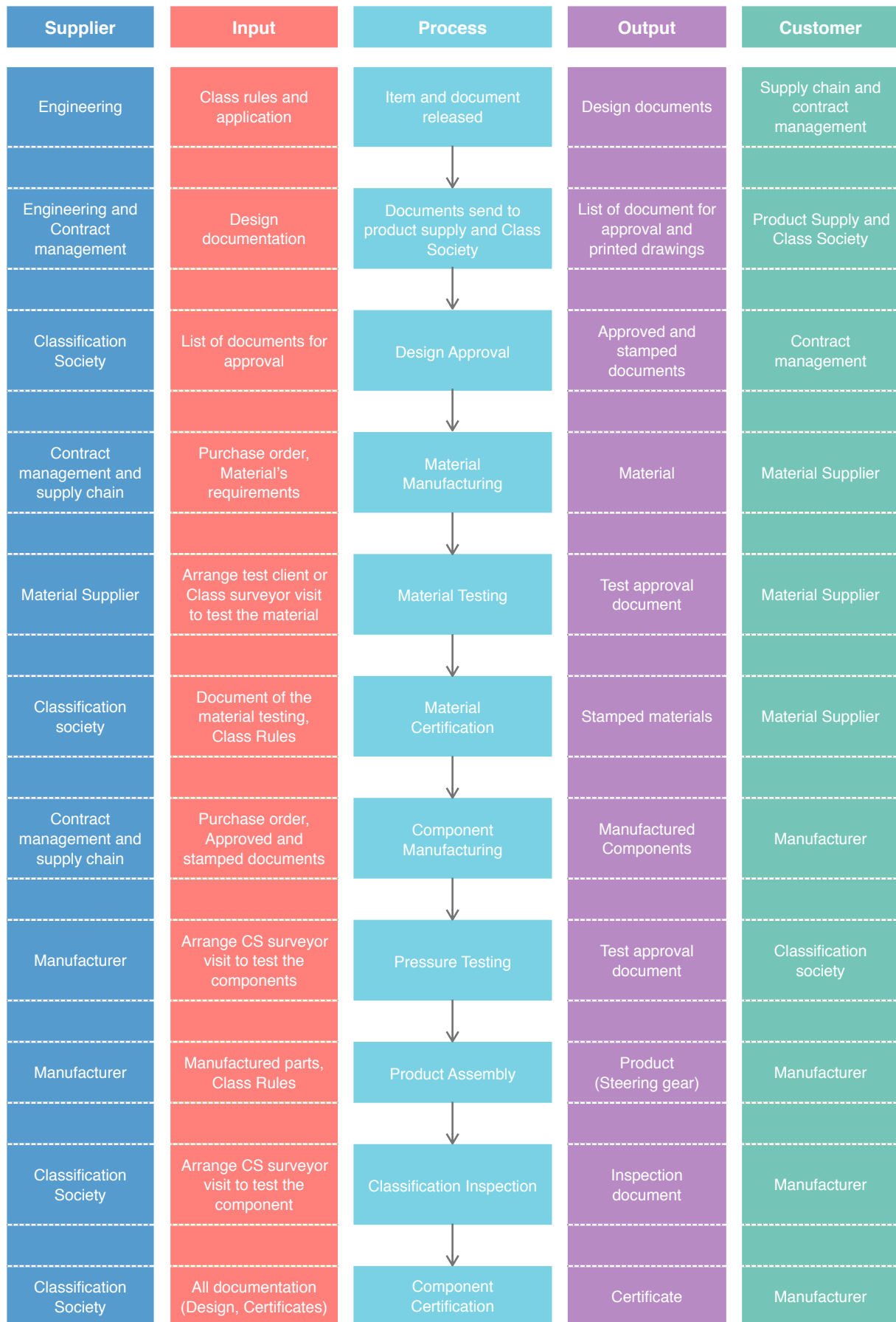


Figure 3.11. SIPOC for certification proces of steering gear (direct surveys)

Quality assurance scheme for machinery is new way of certification process where Class Society is reviewing production process. After product certification the company will be able to inspect the product without presence of surveyor. Classification Society will come every six months or annually (depend how is agreed in contract) for inspection only some of the processes to be sure that company is following the agreed processes and procedure of production. The process is presented in the following figure (figure 3.12.).

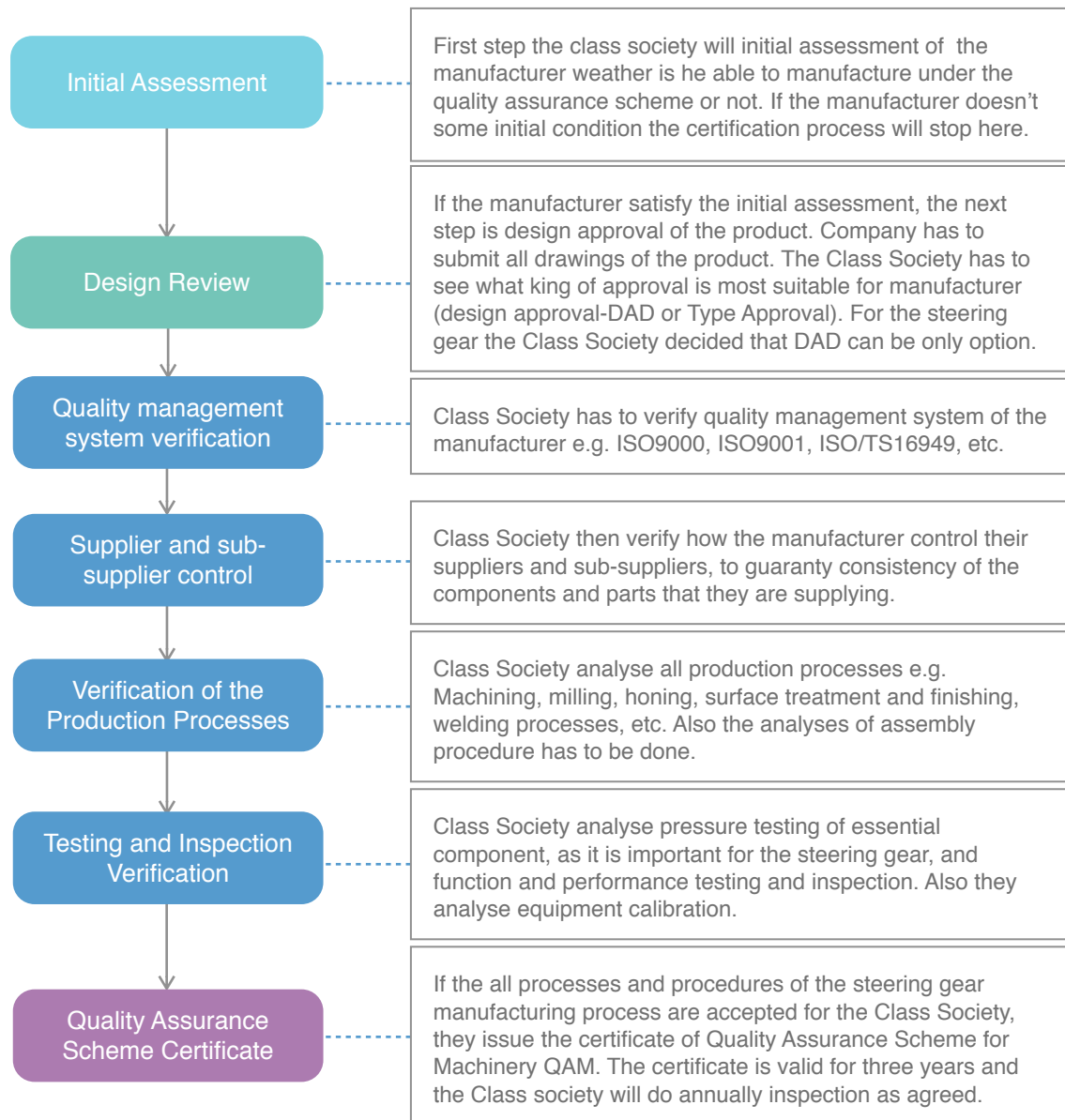


Figure 3.12. Certification process of the steering gear manufacturer, QA scheme

Below the QAM certification process of the steering gear manufacturer (Figure 3.13.) is described in SIPOC (Supplier – Input – Process – Output – Customer) process model for quality assurance scheme inspection.

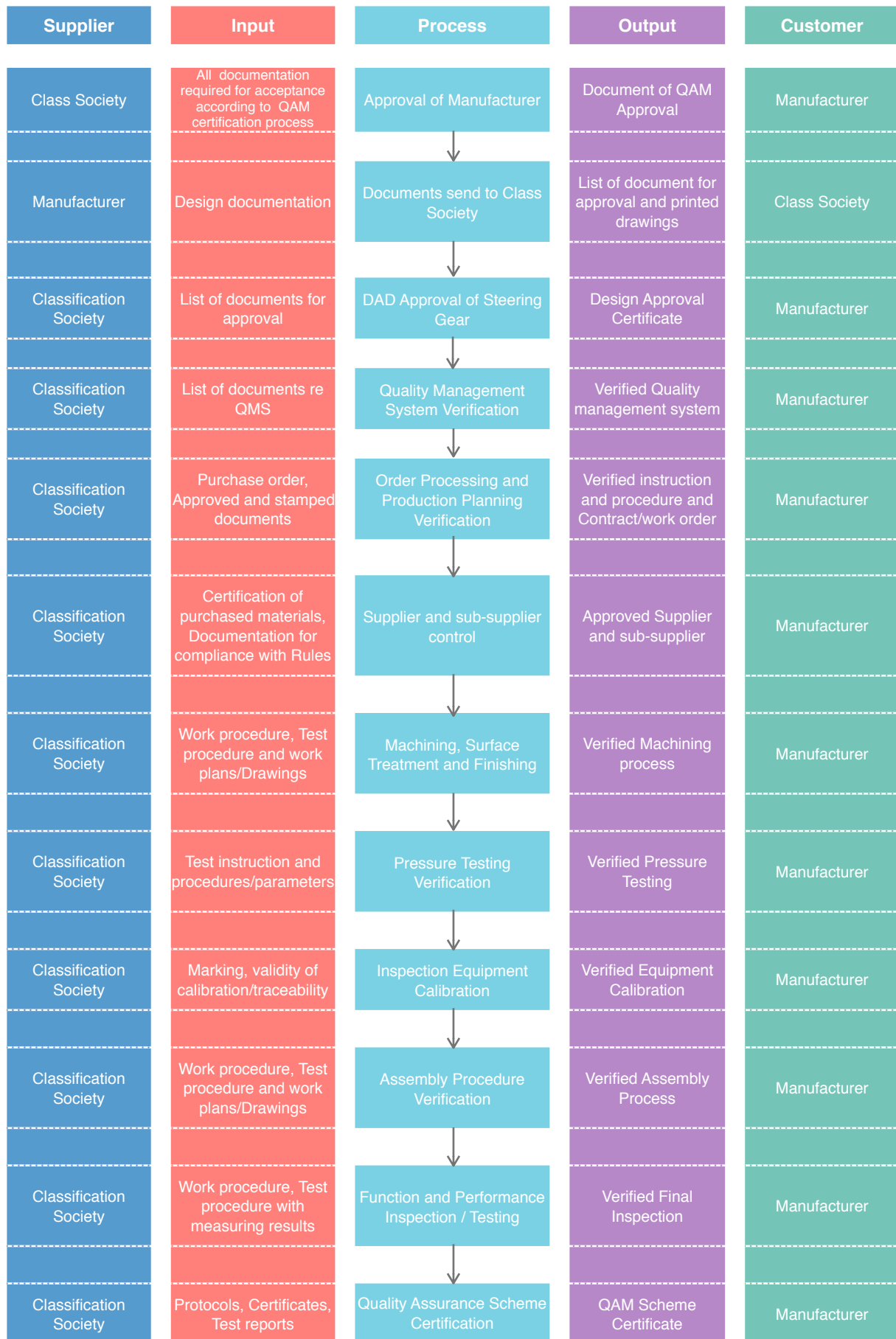


Figure 3.13. SIPOC for QAM certification process of the steering gear manufacturer

### **3.6 Bureau Verities (BV) Certification Scheme**

BV certification scheme of materials and equipment (products) intended to be fitted on board units to be classed or classed with the Society in accordance with the relevant requirements of the Society's Rules for Classification.

All products that can be certificated by type approval are divided into three main categories of products[30]:

1. Products category I<sub>BV</sub>
2. Product category H<sub>BV</sub>
3. Product category D<sub>BV</sub>

#### ***3.6.1 Type Approval of Product Category I<sub>BV</sub>***

Products category I<sub>BV</sub> are certified by the Society individually or per batch in compliance with the applicable requirements (e.g. hull steel plates, anchors, diesel engines, reduction gears etc). Such products may have to comply with design requirements which may include type testing requirements (e.g. diesel engine). For some metallic materials, manufacturing process may have to be assessed through specific testing programmes (e.g. hull steel plates).

Assessment of compliance with production requirements consists in checks and tests made upon applicant's request in the presence of the Surveyor (recognition known as BV Mode II), or it may be applied alternative survey scheme (known as BV Mode I) to products of category I<sub>BV</sub> subject to the agreement of the Society considering the type of product and the quantities produced. The manufacturer has to operate a quality management system certified for compliance to ISO 9001 or to an equivalent standard acceptable to the Society.[30]

#### ***3.6.2 Type Approval of Product Category H<sub>BV</sub>***

Products category H<sub>BV</sub> correspond to products manufactured in series, having to comply with design requirements assessed through type approval procedure, and manufactured by works recognized by the Society (e.g. fuses).

Such products are not required to be certified by the Society individually or per batch. Their compliance with the approved type is solely certified by the manufacturer using his own format of document and marking to allow traceability to the approved type.

### ***3.6.3 Type Approval of Product Category D<sub>BV</sub>***

Products category D<sub>BV</sub> products correspond to products manufactured in series and having to comply with design requirements assessed through type approval procedure without subsequent intervention of the Society at the manufacturing works (e.g. cable ties).

Such products are not required to be certified by the Society individually or per batch and the manufacturing works is not required to be recognized by the Society. Their compliance with the approved type is solely certified by the manufacturer using his own format of document and marking to allow traceability to the approved type.

### ***3.6.4 Recognition (Known as BV Mode II)***

Traditional survey - Recognition BV Mode II is BV conducts works assessment for recurrent requirements (traceability procedures etc.). The Society attends to tests at manufacturer's premise for each unit or lot to be certified.

The following documents are requested to be submitted by the manufacturer to the Society [30]:

- Outline of the company, e.g. organisation and management structure
- Quality system certification to ISO 9001 or equivalent, if available
- Quality manual and/or documented procedures covering the items listed for the Audit (see below)

Where the audit includes a visit of the manufacturing and testing premises. The scope of the audit may be reduced by the Society, taking into consideration existing certification to ISO 9001 standard or equivalent.

For products of category I<sub>BV</sub>, the recognition process is to be regarded as a general audit which does not replace the attendance of the Surveyor to the required tests and examinations.

For products of category H<sub>BV</sub>, the audit is focused on the production process of the type approved products.



### ***3.6.5 Recognition For Alternative Survey Scheme (Known as BV Mode I)***

The alternative survey scheme BV Mode I may be applied to products of category I<sub>BV</sub> subject to the agreement of the Society considering the type of product and the quantities produced.

The alternative survey scheme (BV Mode I) allows the manufacturer to carry out the required tests and examinations partly or totally without the attendance of the Surveyor. The alternative survey scheme applies only to examination and testing operations carried out by the manufacturer or by its subcontractors under its control. It does not include the design review activities which remain to be done as per the relevant procedures for the concerned products.

The manufacturer has to operate a quality management system certified for compliance to ISO 9001 or to an equivalent standard acceptable to the Society. The certified quality management system is to cover the production and testing activities for the concerned products.

The following documents are to be submitted by the manufacturer to the Society[30]:

- Outline of company, e.g. organisation and management structure
- Quality system certification to ISO 9001 or equivalent, together with the last audit report
- Manufacture, testing and inspection plan
- Quality manual and/or documented procedures covering the items listed in Audits (see below)

The manufacturer has to submit a document detailing the examinations and tests that he will carry out before, during and after manufacture for each type of product or line of products concerned by the alternative survey scheme.

Where the manufacturer is subcontracting significant parts of the product, the Society may require to audit the manufacturer's subcontractor.

When necessary to assess the above items, the Society may refer to the relevant articles of the quality management system standard used by the manufacturer and /or to the Society's Rules for classification. All BV's certification options are presented in figure 3.14 and table 3.2.

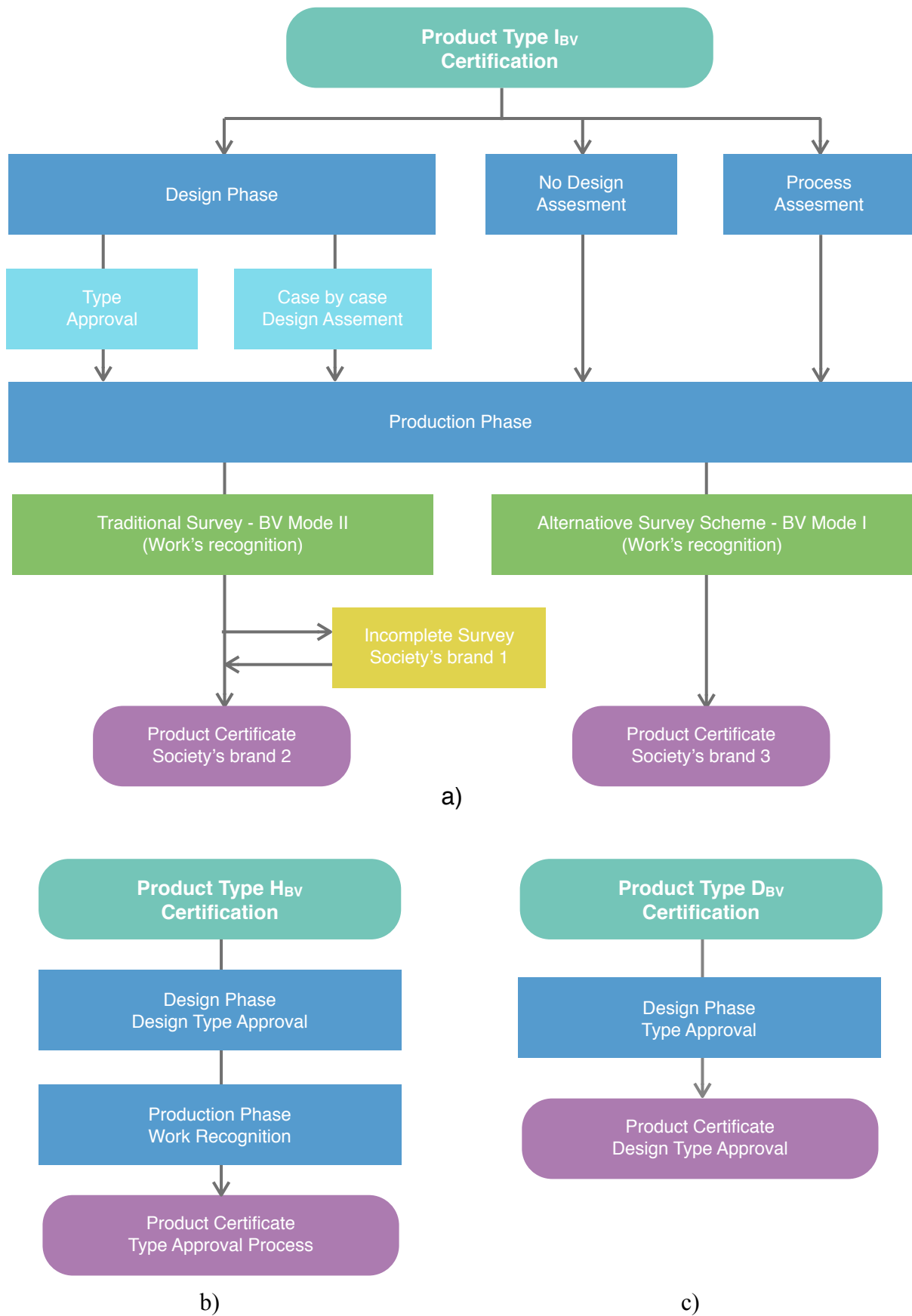


Figure 3.14. BV's certification options flow charts [30]  
 a) product type IBV, b) product type HBV c) product type DBV

Table 3.2. BV's certification options

Product Type	Design	Production	Certificate	
<b>Product type</b> <b>IBV</b>	<p><b>TYPE APPROVAL</b></p> <p>Design review and if required type tests, 5 years validity</p> <p>Product manufactured in series according to a define type, typical: Anchors, diesel engines, reduction gears</p>	<p>Traditional survey (recognition BV Mode II)</p> <p>BV conducts works assessment for recurrent requirements (traceability procedures etc.)</p> <p>BV attends to tests at manufacturer's premise for each unit or lot to be certified;</p>	BV issues a work's recognition certificate for mode II 4 years validity	BV issues a certificate of inspection each time units or lots are intended for BV ships
	<p><b>CASE-BY-CASE DESIGN ASSESSMENT</b></p> <p>Products manufactured for a given ship, typical : propeller shaft, propeller, rudder stock etc.</p>			
	<p><b>NO DESIGN ASSESSMENT</b></p> <p>Typical: Binge pumps</p>	<p>Alternative survey (recognition BV Mode I)</p> <p>Usually for product with mass production process, BV agrees to delegate attendance to tests at manufacturer's premise to the manufacturer's quality management for each unit or lot to be certified.</p> <p>Follow-up is made by audits.</p>	BV issues a work's recognition certificate for mode I 4 years validity	Manufacturer's issues a certificate of conformity endorsed by BV each time units or lots are intended for BV ships
	<p><b>PROCESS ASSESSMENT</b></p> <p>Process description and Tests Approval Certificate 5 years validity Typical : Hull plates, welded pipes</p>			
<b>Product type</b> <b>HBV</b>	<p><b>TYPE APPROVAL</b></p> <p>Design review and if required type tests, 5 years validity</p> <p>Products manufactured in series according to a defined type, typical : circuit breakers, contractors, switches, welding consumables, shop primers,</p>	<p>Assessment of production to verify conformity to the type approved</p> <p>Audits of production line</p>	Recognition certificate with 4 years validity	Manufacturer declares that product is conform to the type approved
<b>Product type</b> <b>DBV</b>	<p><b>TYPE APPROVAL</b></p> <p>Design review and if required type tests, 5 years validity</p> <p>Products manufactured in series according to a defined type.</p>	No assessment		

### **3.7 Det Norske Veritas (DNV) Certification Scheme**

The applicable chapters of the DNV rules define the extent of the certification that is required. Product certification includes normally both[29]:

- approval of the product design, and
- survey during the production and / or of the final product.

The survey will be carried out at the manufacturer's premises. The design approval will either be on a "case by case" basis or follow the procedure for Type Approval.

#### ***3.7.1. Design Approval "case by case"***

When the design approval is performed on a "case by case" basis, documentation of the design shall be submitted for approval for each application / project.

In addition to the traditional ways of design approval, DNV offers digital design approval named "eApproval". Through a secure service on DNV's web tool, manufacturers can submit and receive documentation over the internet.[29]

#### ***3.7.2 Survey during production, "case by case"***

The objective of the surveys carried out by the DNV surveyor during the production and of the final product, is to verify and document that the final product is in compliance with the specified rule requirements and the approved design documentation. The surveyor must be given access to all areas and facilities for production and quality control.

#### ***3.7.3 Survey during production on the basis of a Manufacturing Survey Arrangement***

As an alternative to survey during production, "case by case", the survey may be carried out on the basis of an agreed Manufacturing Survey Arrangement (MSA). A Manufacturing Survey Arrangement (MSA) is a agreement between the manufacturer and DNV which describe the scope, requirements, acceptance criteria, documentation and the roles and responsibilities of the manufacturer and DNV in connection with the production assessment.

When it is agreed in the MSA that the majority of the required survey items are being completed without the presence of a DNV surveyor, the MSA is defined to be a Major MSA, otherwise the MSA is Minor. For all Major MSA, the assessment will be performed with

DNV's Manufacturer Product Quality Assessment (MPQA) tool. Validity of the MSA is 4 years.[29]

### **3.7.2. Type Approval**

DNV is operating the following two Type Approval schemes[29]:

- DNV Type Approval
- EU RO Mutual Recognition (MR) Type Approval.

The DNV Type Approval (TA) scheme is a procedure for approval of the design of materials, products and systems. The TA scheme may be used as an alternative to design approval "case by case" when the materials, products and systems are intended for DNV classed vessels.

The DNV TA procedure should normally be used for approval of standard design of products produced in series.

For most products and systems DNV TA is a voluntary alternative for approval of design. However, for certain products and systems as defined in the applicable chapters of the DNV Rules, DNV TA is a mandatory procedure for design approval.

The scope of the DNV TA scheme will normally include the following activities[29]:

- design assessment of documentation
- type testing of the material, product or system
- initial assessment at the TA applicant
- issuance of DNV Type Approval Certificate (TAC).

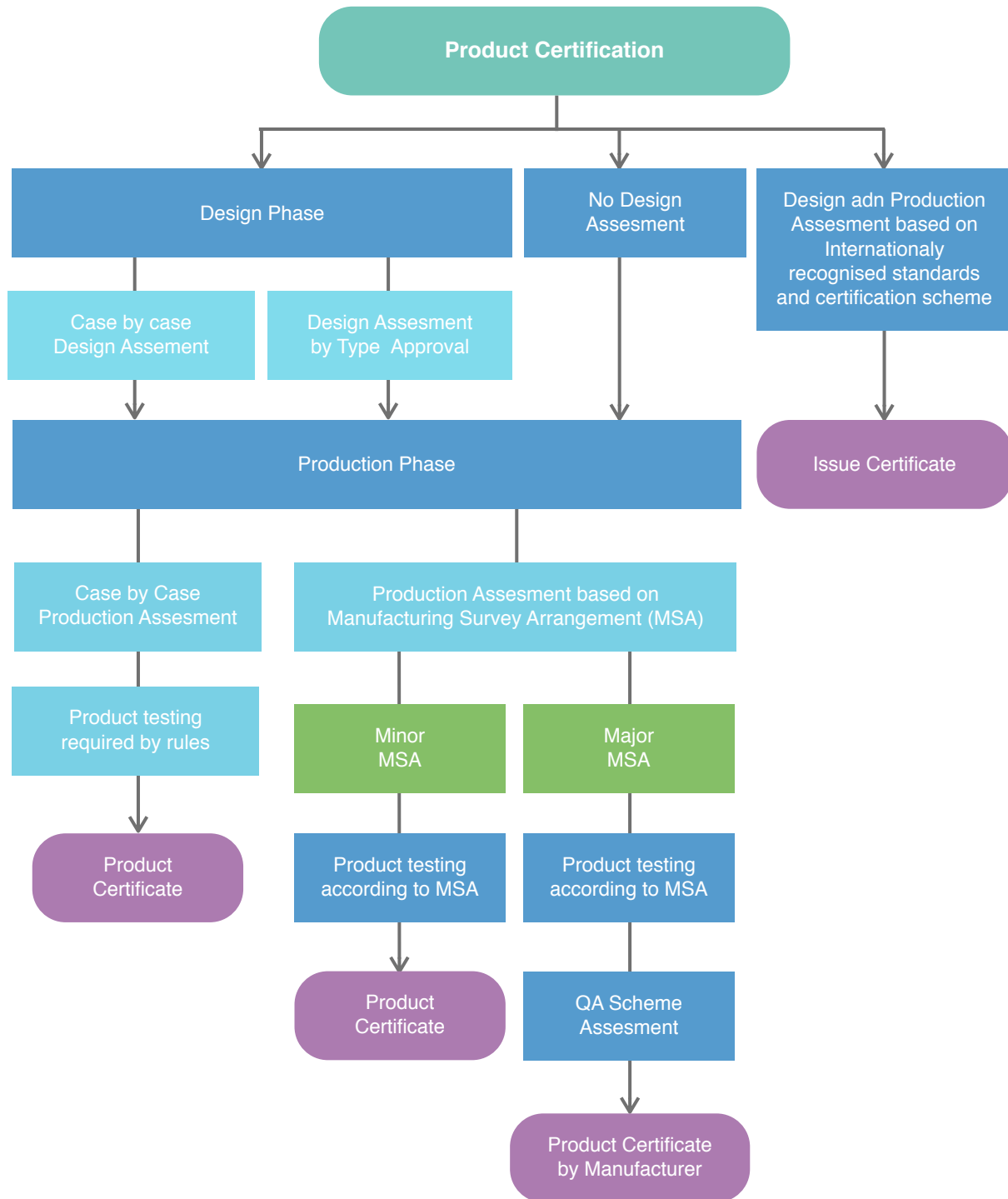
Technical conditions for DNV TA is that there must be specific and applicable design requirements for the product in question in the DNV Rules that are fulfilled and that can be referred to as basis for the TA.

The specified requirements that can be used as the basis for a DNV TA are found in the following standards[29]:

- DNV Rules for Classification of Ships, and/or
- DNV Standards, and/or
- DNV Type Approval Programmes.

When a DNV TAC is issued, it will for most products be valid for 4 years. For some products the validity of the TAC is 2 years[29].

All DNV's certification options are presented in the figure 3.15 and the table 3.3.



Major MSA - a majority of the surveys and tests are being completed without the presence of the surveyor

Minor MSA - only a minor part of the surveys and tests are being completed without the presence of the surveyor

Figure 3.15. DNV's certification options flow charts

Table 3.3. DNV's certification options

Module		Option	Manufacturer	DNV	
DESIGN	Mod. 1	Design Assessment not Required	- Keep technical documentation at disposal for DNV		
	Module 2	“Case by Case” Design Assessment	- Submits required technical documentation to DNV for assessment	- Assessment the documentation versus rule requirements - Issues design assessment documents confirming compliance with requirements for a specific application	
	Module 3	Design Assessment by Type Approval	- Perform Type Testing as required - Submits required technical documents to NV for assessment	- Witnesses Type Testing as relevant - Asses the technical documentation versus Rule requirements and for general application of the product type for a specific period of time	
	Module 7	Design and Production Assessment based on internationally recognized standards and certification scheme	As required by the standards: - Keeps technical documentation - Performs inspection and testing - Documents compliance with the standard		
PRODUCTION	Module 4	“Case by Case” Production Assessment	- Performs all testing requirements by the rules - Records test results and issues work certificate and test report confirming compliance with requirements	Performs inspection and witnesses testing as requirements by the rules Issues DNV certificate (NV) marks the product	
	Module 5	Production Assessment based on Manufacturing Survey Arrangement	Major MSA	- Operates a quality systems accepted by DNV - Performs inspection and testing according to an established MSA - Documents compliance with requirements in accordance with an established MSA	- Performs inspection and witnesses testing according to an established MSA - Issues DNV certificate (NV) according to an established MSA - Marks the product
			Minor MSA	- Operates a quality system certified by DNV or another accredited certification body - Performs inspection and testing according to an established MSA - Issues Certificate according to an established MSA	- Performs inspection and testing according to an established MSA - Performs product quality assessment - Endorses NV certificate issued by the manufacturer - Issues DNV certificate (NV) according to an established MSA
	Module 6	Production Assessment not Required	- Operates a quality system for inspection and testing accepted by DNV - Marks the product with references to Type Approval Certificates		

### 3.7 American Bureau of Shipping (ABS) Certification Scheme

ABS Type Approval for a product enables the product selection by ship designers, builders and owners for placing onboard an ABS-classed vessel. A Type Approved Product is expedited through the Unit Certification process. ABS Type Approval requires a contract between ABS and the original equipment manufacturer (OEM) – the person or legal entity that has legal or patent rights to produce the material, component, product or system.

The main ABS certificates of the type approval categories are following[28]:

- Product Design Assessment (PDA) certificate
- Manufacturing Assessment (MA) certificate
- Confirmation of Type Approval certificate
- Product Quality Assurance (PQA)
- Marine Equipment Directive (MED) Module B certificate
- Marine Equipment Directive (MET) Module D, E, F or G certificate

An ABS Product Design Assessment (PDA) is the assessment of a product for use on a variety of ABS-classed ships following a technical evaluation. The PDA reduces the turnaround time for approval on a specific ship. When a specific ship is chosen, ABS technical staff verify that the product, as already assessed, is suitable for use. This can be done with a simple review of the PDA and does not require submittal of further documentation from the manufacturer.

To conduct surveys and tests without an ABS surveyor in attendance, manufacturer has to have manufacturing Assessment Certificate (MA) and Product Quality Assessment certificate (PQA).

Manufacturing Assessment (MA) certificate represent ABS surveyor's witnessing that the product can be consistently manufactured according to the Product Design Assessment (PDA). ABS rule also required that testing must be witnessed by an ABS surveyor.

Product Quality Assessment certificate (PQA) may be applied only to mass-produced products that require unit certification. The manufacturer must have a certified quality system and the Manufacturing Assessment (MA) must be valid[28].

All ABC's certification options are presented in the figure 3.16 and the table 3.4.



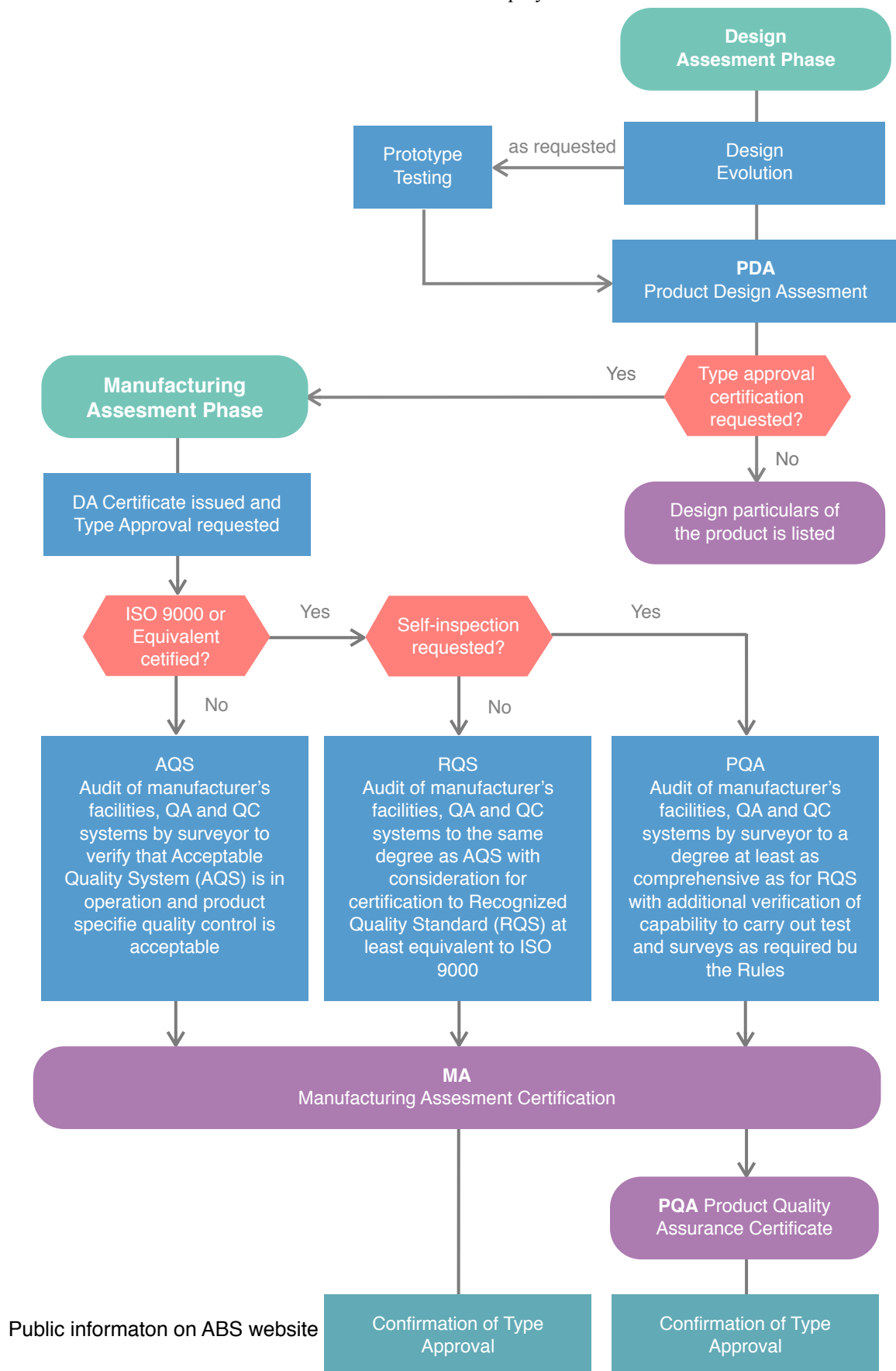


Figure 3.16. ABS’s certification options flow charts [28]

Table 3.4. ABS's certification options

Name of Certificate	Criteria for Issue	Terms of Validity	Consequences of Non-compliance
<b>Product Design Assessment (PDA):</b> Each product may be awarded a PDA. There is no limit to the number of products a manufacturer can have Type Approved.	Evaluation of the product to ABS Rules and/or specified, acceptable national, international or client standards.	Five years, subject to continued compliance with the Rules or other standard used for the evaluation. Any significant change in the design of the product will require reassessment and the issuance of a new PDA.	Reverts to category of PDA Limited, is not eligible for Product Type Approval and is removed from the Type Approved listing on the ABS website after one year.
<b>Manufacturing Assessment (MA):</b> A separate certificate must be issued for each manufacturing facility and for each product.	Valid PDA and satisfactory demonstration that the product can be consistently manufactured according to the PDA. Rule-required testing must be witnessed by an ABS surveyor.	Five years subject to annual audits and the continued validity of the PDA.	The product may not be listed as Type Approved.
<b>Confirmation of Type Approval</b>	Product must have both a valid PDA and MA.	Valid until the expiration of the PDA or MA (whichever occurs first).	The product may not be listed as Type Approved.
<b>Product Quality Assurance (PQA):</b> ABS may grant unsupervised testing authority to the manufacturer in special circumstances.	The manufacturer must have a certified quality system, the MA must be valid and the product must require unit certification.	Same as the associated MA and subject to semiannual audits.	Reverts to standard MA status, and all Rule required testing must be witnessed by an ABS surveyor.
<b>MED Module B</b>	Must have valid PDA.	Same as associated with PDA.	Same as PDA.
<b>MED Module D, E, F or G</b>	Must have valid MA.	Same as associated with MA.	Same as associated with MA and manufacturer may not use the "wheel-mark".

### 3.8 China Classification Society (CCS) Certification Scheme

CCS provides various modes of approval according to the categories of marine products for the manufacturer to choose when applying for the inspection of marine product.

According to CCS' Rules and Regulations, there are following approval modes for CCS products certification[30]:

- **Design approval** - to verify that the products comply with the requirements of IMO convention, CCS rules or applicable criteria by way of reviewing the drawings and technical documents and related survey and experiment, such as windlasses, winches, steering gear. Certificate of design approval will be issued after CCS approval. Please find attached the flow chart of Design Approval for information.
- **Works approval** - refers to the approval of the manufacturer's conditions and capability for producing certain type of product, which is granted by the Society based on document review, approval test and field audit.
- **Type approval** - type approval can be divided into Mode A and Mode B.
- **Approval of product test and inspection institutes** - refers to the approval of the product test and inspection institute's conditions and capability for marine and product-specific inspection and test projects which is granted by the Society based on document review, approval test and field audit. Certificate will be issued after CCS approval.

Type approval can be divided into Mode A and Mode B.

**Mode B** of type approval refers to the approval granted by CCS for the Standardized Design and fitness for purpose of the product when CCS confirms that the products, the production and test equipment of the manufacturer, and the system of basic quality control comply with the regulations of CCS rules after the review of the product drawings and technical documents, verification of related technology, approval tests and field audit. For example, after CCS approval of diesel engines and pumps, type approval mode B certificate will be issued. Please find attached the flow chart of mode B type approval for information.

**Mode A** of type approval is the high-level approval to be granted to the manufacturer with high-quality, based on the Mode B of type approval. Mode A of type approval contain Mode B of type approval with appropriate QA system of the manufacturer and reliable quality of the products. For the manufacturer which has obtained the Mode A of type approval, CCS accepts that the field inspection of the surveyor can be replaced partly or totally by the quality statements supplied by quality inspector (designated) of the manufacture. Type approval mode A certificate will be issued after CCS approval[30].

All CCS's certification options are presented in the figure 3.17, 3.18 and the table 3.5.

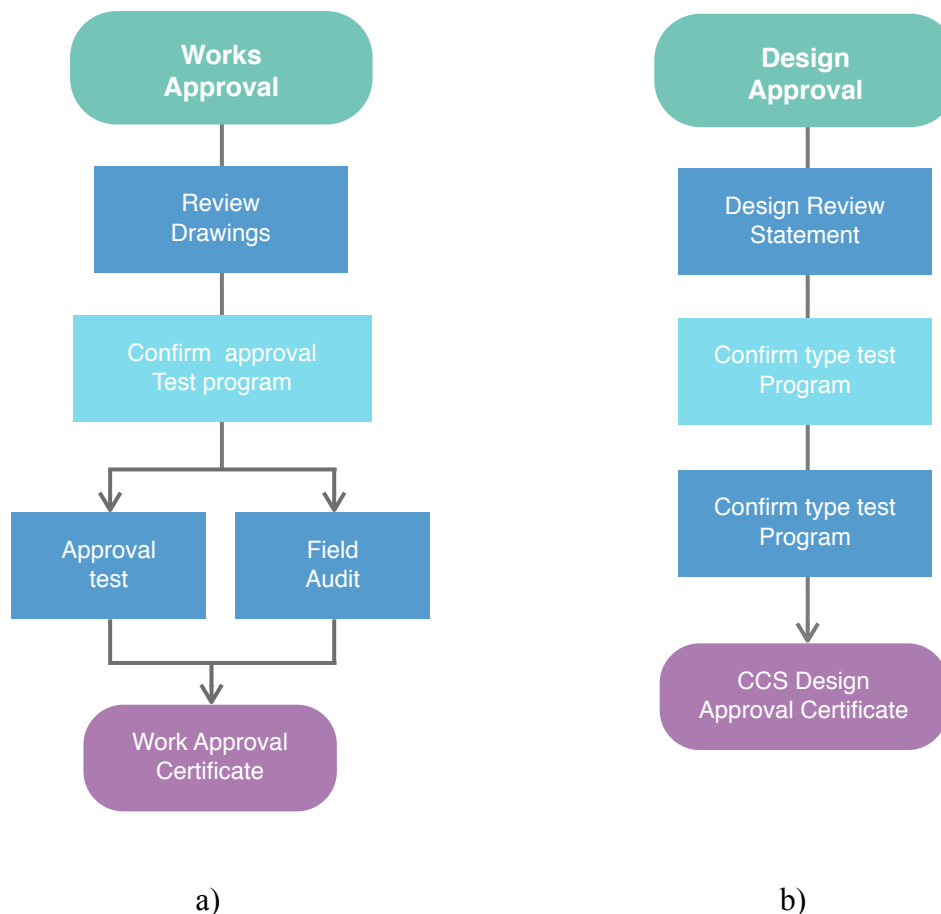


Figure 3.17. CCS's certification options flow charts [30]  
a) Work Approvals, b) Design Approvals

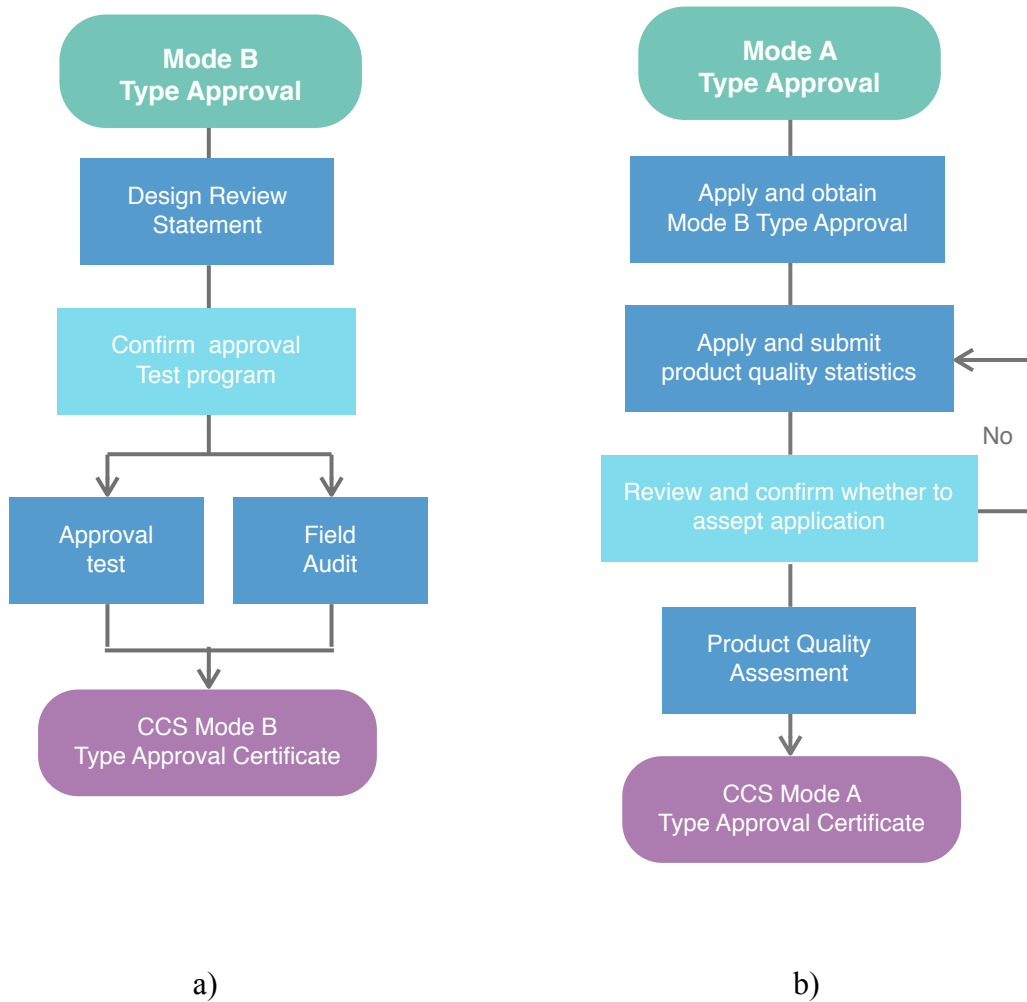


Figure 3.18. CCS’s certification options flow charts [30]  
a) Mode B Approval b) Mode A Type Approval

Table 3.5. CCS's certification options

Mode/Certificate	General Requirement	Terms of Validity	Product inspection after approved
<p><b>Unit/Batch Inspections Products Certificate</b></p> <p>Means the process of evaluating the compliance of the products with applicable requirements through design approval, examination and testing of the final products and/or during their manufacturing.</p>	<p>(1) Examination of drawings and technical documents or keeping them for information</p> <p>(2) Prototype / type test or measurement</p> <p>(3) Inspection and test during manufacturing and / or of final products in compliance with 1+2.</p>	N/a	CCS attends to tests at the manufacturer's premises for each unit or lot to be certified
<p><b>Design approval Certificate</b></p> <p>Is part of the type approval and applicable to the design approval procedure for products in the category of equipment and systems. The design approval consists of drawing approval and prototype or type test.</p>	<p>(1) The product design to be examined</p> <p>(2) Prototype / type test</p>	Full-term	CCS attends to tests at the manufacturer's premises for each unit or lot to be certified
<p><b>Type approval Certificate - Model B</b></p> <p>To be capable of producing and testing the products to be approved and have an effective quality control system. Consists of design approval and manufacturing assessment.</p>	<p>The manufacturing assessment consists of:</p> <p>(1) Audit of the manufacturing management system:</p> <p>(2) Audit of the manufacturing process:</p>	4 years	CCS fully or partially attends to tests at the manufacturer's premises for each unit or lot to be certified
<p><b>Type approval Certificate - Model A</b></p> <p>To be qualified for type approval B and in addition, to establish and maintain a quality assurance system complying to meet the specified level of product quality consistently.</p>	Type approval B and in addition, to establish and implement a quality management assurance system.	4 years	Periodical audit
<p><b>Works Approval Certificate</b></p> <p>The works approval applies to the products of which the quality assurance is achieved by means of batch production in a continuous process or completely based on production technology and process.</p>	<p>The procedure of works approval consists of the following 3 parts:</p> <p>(1) Document review;</p> <p>(2) On-site audit;</p> <p>(3) Type test.</p>	4 years	CCS fully or partially attends to tests at the manufacturer's premises for each unit or lot to be certified

### **3.9. Comparison between Classification Societies**

Organizations such as classification societies exist only in the marine industry. Today exist certain opinions that a multitude of classification societies actually strangling the marine industry. In conversations with people from the industry, general opinion is that more classification societies is bad for the marine industry. However, in an interview with one of the directors of VDMA when we came on this subject, he had opinion that multitude of classification societies can be very beneficial for the industry, because there is a competition among them and prevents a monopoly, but only if the industry can use a benefit of the competitiveness. His view is that today the marine industry can't use that benefit, except in the case of the EU mutual recognition agreements.

The author also shares the opinion that the multitude of classification societies is beneficial to the industry, even if the manufacturers can not currently use the benefit of the competitiveness between the Classification Societies. This is primarily because the competitive relationship between the classification societies contribute to continuously improving their services towards the manufacturers. All classification societies want to be the best in class, in that competitiveness between them they make great efforts to continuously improve services of the classification societies and often reduction of prices.

The five leading Classification Societies are presented above with their main certification scheme. It can be seen that each Classification Society has very similar certification scheme, but there are some differences that have been identified. One of the noticeable differences is the division of parts into groups, usually according to the essentiality or the complexity. Some of Classification Societies permits an "partially self-certification", where some parts of the product are self-certified, while other parts have been certified on case by case basis.

For a comparison of classification societies, the following factors were considered:

- ✦ QA scheme based certificate
- ✦ Products division
- ✦ Different option of QA scheme certificate
- ✦ Upgrading existing certificate to obtain higher category certificate
- ✦ Validity of certificate
- ✦ Scheduling approving agreement
- ✦ Internet based certification (e-approval)

Comparison of classification societies is presented in the following table 3.6.

Table 3.6. Comparison of the classification societies' certification schemes

	LR	BV	DNV	ABS	CSS
Offering Type Approved Manufacturing	<i>yes</i>	<i>yes</i>	<i>yes</i>	<i>yes</i>	<i>yes</i>
Dividing products on categories	<i>no</i>	<i>yes</i>	<i>no</i>	<i>no</i>	<i>yes</i>
Offering the Manufacturer inspection without surveyor attendance	<i>yes</i>	<i>yes</i>	<i>yes</i>	<i>yes</i>	<i>yes</i>
Dividing Quality Assurance Assessment on categories	<i>no</i>	<i>no</i>	<i>yes</i>	<i>no</i>	<i>no</i>
Higher level of certification based on the previous certificate	<i>no</i>	<i>no</i>	<i>no</i>	<i>yes</i>	<i>yes</i>
Validity of Certificate	<i>3 years</i>	<i>4 years</i>	<i>4 years</i>	<i>5 years</i>	<i>4 years</i>
Offering internet based certification	<i>yes</i>	<i>no</i>	<i>yes</i>	<i>no</i>	<i>no</i>
Certification Agreement for Scheduled Approval of products	<i>no</i>	<i>no</i>	<i>yes</i>	<i>no</i>	<i>no</i>



## 4. BUSINESS ASSURANCE IN ANOTHER INDUSTRIES

### 4.1. Automotive Industry

The automotive industry began its activity in the 17th Century, using steam as propulsion element. After significant progress in gas-powered engine design, the first petrol engines emerged in 1889. In the early 20th Century, mass production of automobiles begins in the USA, being leaders in automobile manufacturing. Some years later, European manufacturers learnt the lessons and built manufacturing plants in the UK, France, Germany and Italy. [5]

In 1939, General Motors (mainly) and Ford were the leading company in the US market, Opel and Mercedes-Benz in Germany, Renault, Peugeot and Citroën in France, and Morris, Ford, Vauxhall (of General Motors), Standard and Rootes (Jaguar, Rover and Rolls-Royce makes) in the United Kingdom. Japanese car industry arose in the sixties, with a more competitive and aggressive philosophy of work, based on quality principles.

The automotive industry has undergone a concentration that accelerated greatly in the postwar years and today, the world has 65 big international carmakers which produce millions of vehicle. Some information about produced vehicle worldwide by years are given in Fig. 4.1.

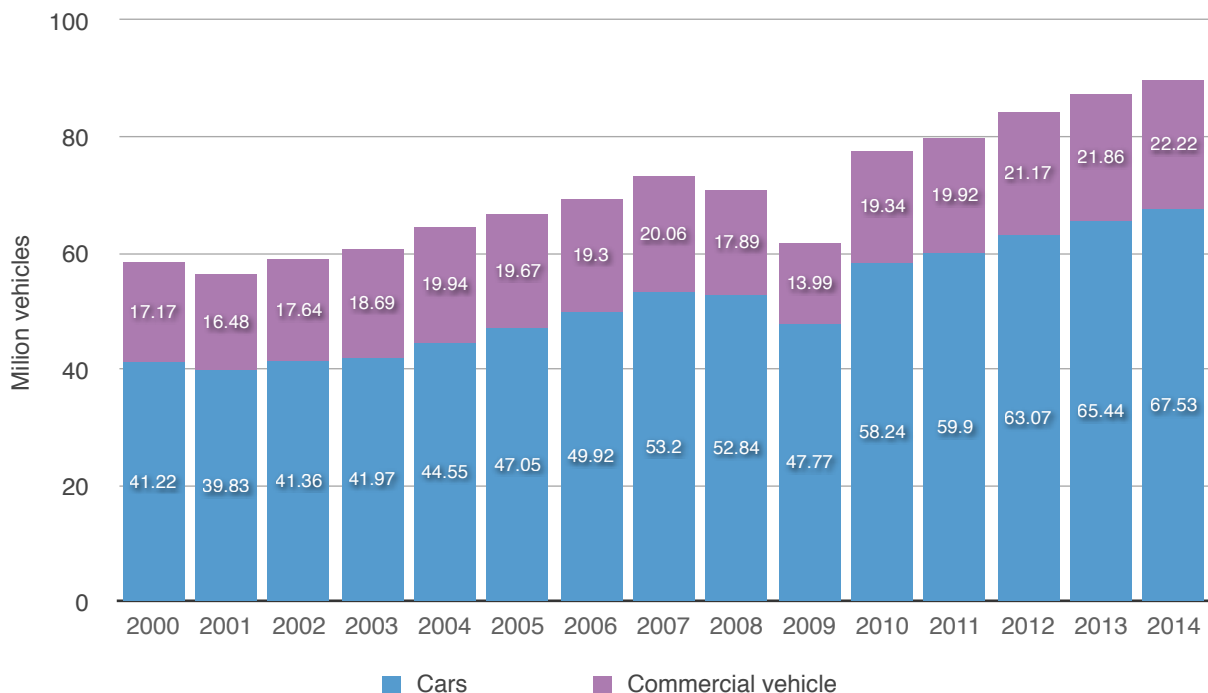
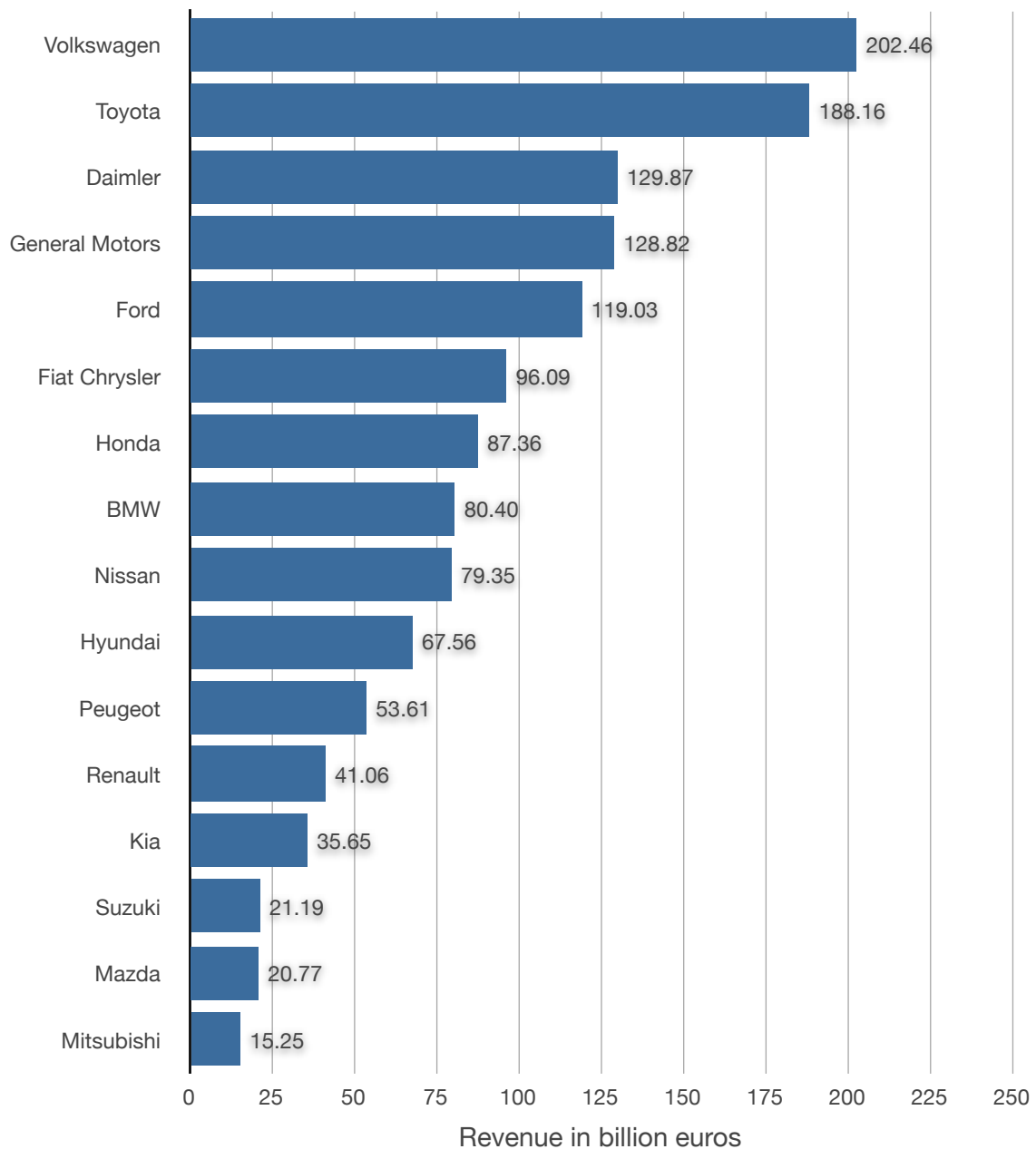


Figure 4.1 Worldwide automobile production from 2000 to 2014 (in million vehicles) [35]



4.2. The leading automotive manufacturers worldwide in 2014, based on revenue (in billion eur.) [36]

The automotive industry has very massive production which value is in billions of euros by year, some information of revenue in 2014 for the leading automotive suppliers are presented in Fig. 4.2.

The cost of designing and manufacturing motor vehicles is very high, owing to the complexity of the vehicles, the rigid quality and safety standards involved in making them, plus the rigorous testing required and the frequency of design change. Thus design and manufacture are carried out in a very few very large companies. Increasingly in recent years, portions of the product design function have been shared by major automobile makers with

their supplier companies. This sharing has added a dimension to the responsibility for quality assurance.

#### ***4.1.1. Quality in the Automobile Business.***

The word “quality” has taken on new meaning in the automotive industry over the past two decades. No longer is quality simply a statistical scorecard on freedom from defects or the measurement of fit and finish. Today, quality has a much broader meaning that involves a customer’s inner feelings about a product and the company that offers it.

The new definition of quality takes in the basics of performance, comfort, environmental suitability, and affordability, but it adds certain elements of what is known as “production quality”, related to the maker’s ability to perform consistently better, and “ownership quality”, which deals with customer satisfaction.

Two other significant shifts have occurred in recent years to raise the level of quality and quality consciousness in the automotive industry. One is the industry’s move to anticipating customer requirements rather than responding to them, as in the past. Increasingly, automakers have employed sophisticated demographic and other studies to learn more about tomorrow’s consumer, whereas in the past the industry relied on comments from customers as information was gathered for product development.

The other important change is the increase in closeness between automakers and their key suppliers. In the past, suppliers tended to be treated as vendors and were selected mainly on the basis of price and delivery capabilities. Today, the industry’s key component suppliers are nearly full partners with the major companies they supply, with both automaker and supplier reaching into one another’s designs, plans, and quality-improvement mechanisms. This increased confidence, trust, and reliance serve to form shared-destiny relationships that are crucial to the improvement of quality in the automotive industry.[1]

There are three dimensions to quality in the automotive industry: quality in product, quality in production, and quality in ownership. Quality in product is the product’s overall ability to perform required functions.

Quality in production is the ability to produce consistent quality as designed while still meeting volume and cost targets. Within this important dimension are four functions. The first is production of a quality product, measured by defects per hundred. The second ensures

operational quality, which is the plant's ability to introduce new models, remain flexible, and still maintain consistency.

Efficiency is third and is the key to producing even higher quality as volume increases. The fourth production function is cost. The plant must be able to produce an affordably priced product at a profit.

Quality in ownership is the overall ability to satisfy customers throughout their ownership life cycle. This is a critical dimension of quality, but it is the one least understood.

#### ***4.1.1.1. Supplier Relations***

Supplier support and supplier partnerships become increasingly important in a lean-production environment. By developing trust between manufacturer and supplier, many mutual benefits can be achieved.

The component-supplier community can be immensely helpful to the automobile manufacturer in providing design expertise. If the manufacturer provides performance specifications to the supplier, leaving the component company to proceed with design, costs to the automaker can be sharply reduced. To support this activity, the manufacturer must allow supplier representation in the early phase of vehicle development—a big step in the partnering philosophy. This also requires agreements to allow suppliers to invest in development costs with some assurance of being awarded the business.

The other element of trust involves suppliers opening their books and sharing costing information to support the manufacturer's objectives. This is not a short-term activity, and it requires a great deal of interface between the management teams of both the supplier and the manufacturer to develop the required trust and support. This cooperation is essential for long-term competitiveness in the automotive arena.

#### ***4.1.1.2. Quality Assurance by the Supplier***

As with other supplier activities, communication is critical for both supplier and manufacturer to understand the supplier quality assurance activities. This begins with early supplier involvement in the development process. Once the product is agreed on, designed, developed, and prototyped, four basic steps are key to ensuring customer satisfaction with the product[1]:

1. Product approval
2. Process review
3. Feedback
4. Continuous improvement

*The product approval process* - This process contain three main steps:

- a. Verification of understanding and agreement on specifications.

The supplier must understand the manufacturer's expectations and be able to deliver timely production quantities consistently on that level. The supplier also must understand the broader system and know how each component fits into it.

- b. Initial sample approval.

Samples provided for testing must come from production lots, not from laboratory or prototype production, if production capability is to be measured properly. All systems require first-production-piece verification. The additional requirements for sample size, test requirements, and reporting format may vary, but the intent is that the supplier must use this process to verify that expectations for continuous mass production can be met. On completion of this activity, the supplier will submit the part and information to the manufacturer for review. If all criteria and expectations are met, the supplier is given formal, written approval for production to begin. Should a concern arise, it must be addressed immediately to ensure that the part meets expectations and that timing is not delayed.

- c. Comparison of test methods.

The approval process should include a check of the compatibility of test methods. The supplier should include the test data with the test certificate attached to samples, including any information about accelerated life testing and destructive testing. The supplier should be given the automobile company's test results in order to discover and correct any differences in testing techniques.

*Process review* - A common practice with new suppliers is to audit the production process prior to awarding business. Process reviews of current suppliers also are conducted periodically. During the audits, discussions are held on improvements based on a comparison

with other suppliers and the experience of the auditor. Also, suppliers may have process improvements or changes that require approval or on-site review by the manufacturer. On-site supplier visits can be useful, since continuous improvement activities will strengthen the process, partnership, and product quality.

*Feedback* - Communications between the automobile company and the supplier must be open, whatever the topic. The supplier should expect honest, fact-based feedback from the manufacturer. The better the information provided, the quicker and more responsive will be the supplier's reaction. This is a true test of both partners' ability to give detailed information and respond quickly with a detailed, concrete action plan.

*Continuous improvement* - The supplier's work force should be made to understand that simply maintaining the present level of quality is not enough and that constant effort must be applied in the pursuit of improvement. The manufacturer's quality assurance group can help spearhead continuous improvement throughout the supplier firm by making available trainers and training materials; fostering quality-improvement competition between work shifts, departments, and teams; meeting with supplier teams to discuss quality issues; and recognizing continuous improvement by means of on-site supplier award presentations.

Automobile companies exercise control over suppliers in several ways. Some of these, such as the process of supplier selection, joint quality planning, and supplier quality assurance, take place before production.

An annual review of a supplier's facilities is normally conducted to ensure that the supplier is adhering to federal requirements and quality control plans in system testing and document control activities. By contract, suppliers must notify manufacturers of process changes, so documentation and the actual process can be reviewed during the visit.

#### ***4.1.2. Quality Standards Development in Automotive Industry***

From 1950's through 1960's quality assurance practices were dominated by receiving inspection, outgoing inspections and statistical quality control of works in progress, whereas during 1970's and 1980's they were complimented by statistical process control, internal quality audit, and supplier's quality audit using customer set standards. While each customer was setting its own quality standard. Very soon numerous customer's quality standards were created all over the world, which imposed severe stress on many suppliers of automotive parts and sub-assemblies, particularly, those who wanted to supply more than one customers for expanding their customer base.[7]

After the arrival of the NATO Quality Control System standards for military applications, the Quality Panel of the UK Society of Motor Manufacturers develop an equivalent standard for non-military applications. They developed BS 4891, that was published in 1972. In 1974 this was followed by BS 5179 with the title “Operation and Evaluation of Quality Assurance Systems”.

In that time each manufacturer had a quality assurance related manual containing his own requirements and suppliers have to make an effort to fulfill them, where this issue becomes quite complicated when suppliers work for several manufacturers at the same time.

In early 1990s, in order to bring harmony (with the attempt to bring consistency) among all customers standards in world market places, representatives of the Institutes of Standards of various countries including U.S.A., Canada, U.K., France, Germany, Netherlands, and Switzerland, come together in Geneva, Switzerland, and developed a new common international standard for all quality systems around the world, known as "ISO-9000 Series of Quality Standards". [7] The standard recognized well and in 1990s, ISO-9000 became the predominant quality standards accepted by many suppliers with the expectation of supplying multiple customers. However, ISO-9000 was designed as a generic standard with wide flexibility applicable to all kinds of companies belonging to wide spectrum of industries.

Because of the standards's (very wide flexibility) general nature and increasing demand for specializations and focus of manufacturing processes, the big three automakers of the United States (Chrysler, Ford and General Motors), did not accept ISO-9000 as their suppliers' quality audit standard, and they founded a working group in order to harmonize their different

requirement manuals. In 1994 the group developed a set of more rigorous Quality Standards, known as QS-9000 which includes all twenty elements of ISO-9000 as the core requirements. They applied QS-9000 to all internal and external suppliers of raw materials, components, sub-assemblies, and service parts in their global supply chains.[7]

The German automotive sector also reconsidered this issue because of the increased competence, the aim of being more competitive, costs reduction, etc. and was established the “Verband der Deutschen Automobilindustrie“ (VDA) in Germany. VDA organisation makes the VDA 6 “Qualitätsstandard der deutschen Automobilindustrie” standard whose target is to allow for assessment under comparable conditions of different quality management systems. Similarly to these, two more standards also arised: the Evaluation Aptitude Quality Supplier (FLAA) in France (1994), quality system standards for Citroën, Peugeot and Renault, with regard to their suppliers and the Association of Quality System Evaluators (AVSQ) (1995) in Italy.

Lately, the automotive industry follow the globalization tendency for harmonizing the different regulations on quality management that had arisen in the automotive industry. The latest result of this globalization effort is the UNE-ISO/TS 16949 standard, which replaces the QS 9000 standard. The first edition of this technical specification (year 1999) was mainly based on the ISO 9000:1994 standard.[5]

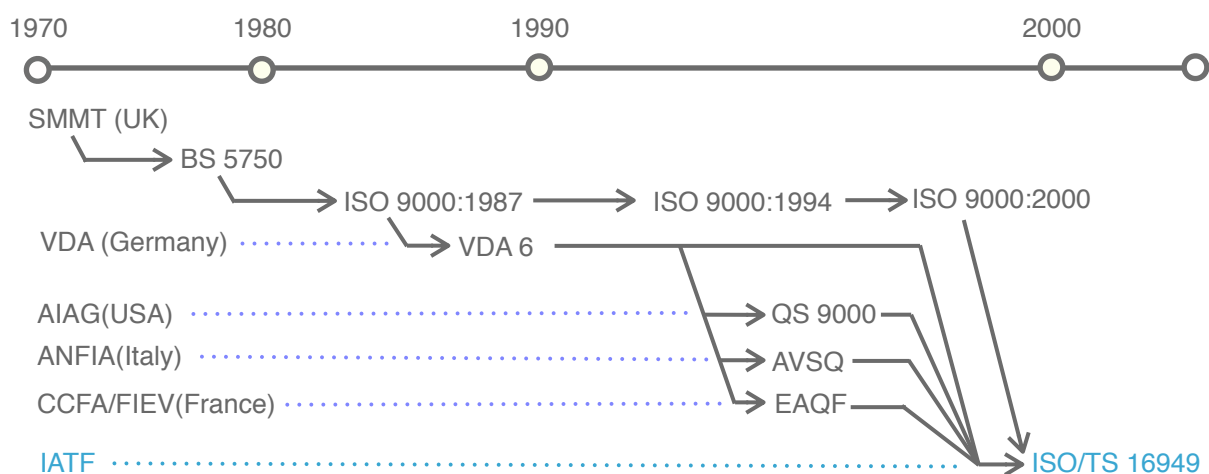


Figure 4.3. Evolution of standards in Automotive industry [9]



### ***4.1.3. ISO/TS 16949 international quality standard***

The International Automotive Task Force (IATF) and the Japanese Automobile Manufacturers Associations (JAMA) produced TS 16949 with support from ISO Technical Committee 176 (TC 176). Based on ISO 9000, TS 16949 is an international fundamental quality management system (QMS) specification for the automotive industry.

This technical specification incorporates section 4 of ISO 9001:1994 and includes requirements taken from QS-9000, VDA 6, AVSQ '94, and EAQF '94 and some new requirements, all of which have been agreed by the international members (see Fig.4.4). [9] The standard applies to all manufacturers in the automotive supply chain worldwide for cars, their parts, components or systems. This is a useful framework to understand the quality planning of the product in general. Broadening the project management concept, this standard requires the establishment of a method so that the Product Realization Process is measured up by means of specific milestones, including the corresponding management analysis and revision. Factors to be accounted for include quality, risks, costs and deadlines. [5]

Some of benefits for a ISO/TS 16949 certified company are:

- ▶ Improved processes and product quality,
- ▶ Reduced need for multiple second and third party audits,
- ▶ Increased confidence in global procurement,
- ▶ Reduction of production variations and improved manufacturing efficiency,
- ▶ Common quality system approach for subcontractor development.

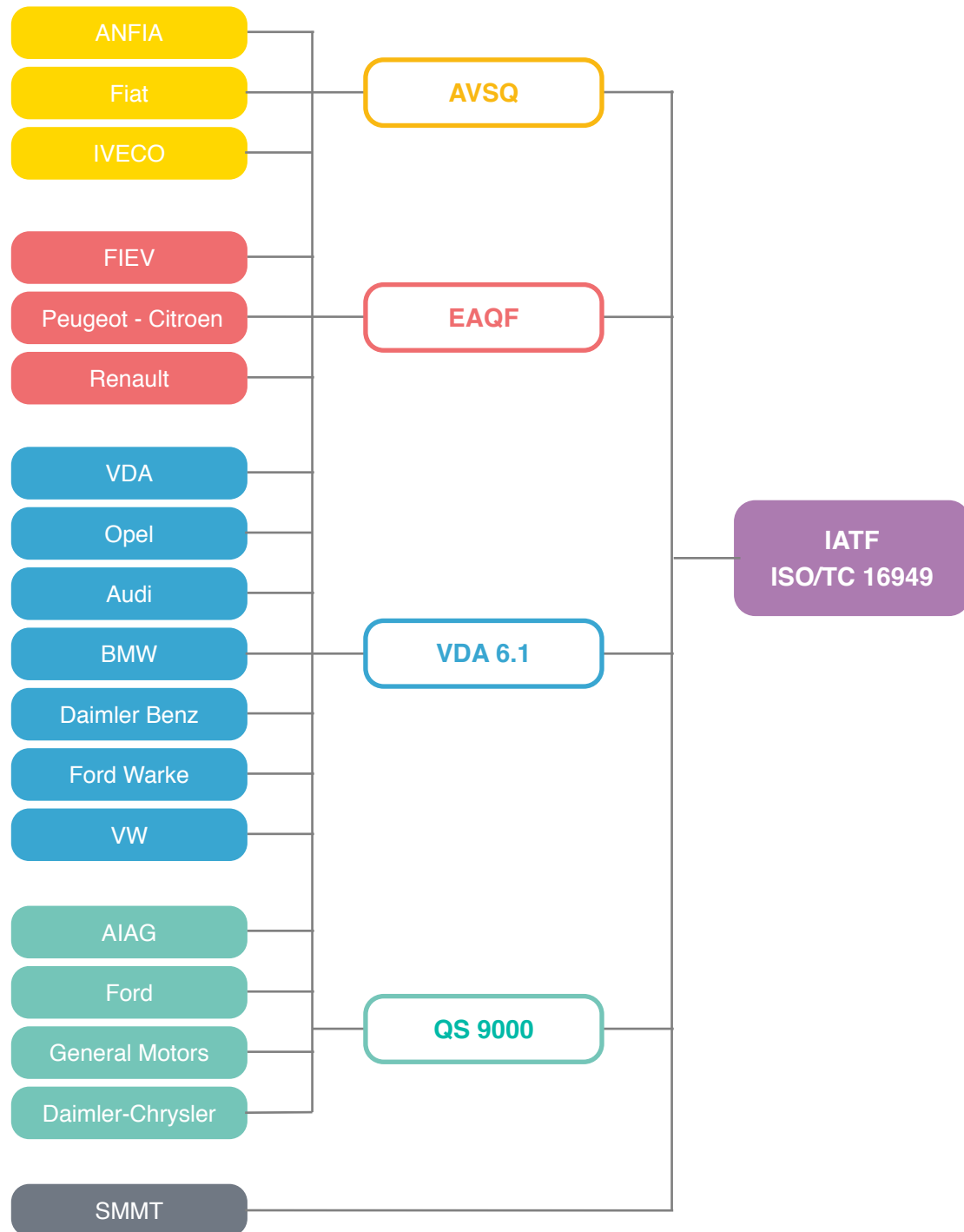


Figure 4.4. Contributors to ISO/TS 16949 [9]

**Product and process quality** will be improved as a result of implementing several new requirements, including:

- Goal setting, measurement, and review
- Customer satisfaction measurement
- Product safety
- Compliance with regulations
- Process design management
- Application of common tools and techniques
- Regular measurement of quality system performance
- Accreditation of inspection, test, and calibration laboratories
- Making staff aware of the impact of nonconformities on customers

**Reduced need for multiple second and third party audits** - if a supplier supplying customers in the USA, France, Italy, and Germany may be subject to audit by one or more of their customers because of the customer's lack of confidence in quality assurance schemes other than its own. ISO/TS 16949 represent common standard and the associated registration scheme, thus, it will not be necessary to perform any further quality system audits of ISO/TS 16949 registered suppliers.

**Increased confidence in global procurement** - with one global scheme, disparities between the various schemes at a national level should be eliminated. This will give a vehicle manufacturer in one country procuring product from another country the same level of confidence as would be obtained from the home country.

**Common quality system approach** - many subcontractors supply product or services to several vehicle manufacturers, therefore by harmonizing the standards, variations in the approach to subcontractors will be minimal.

#### 4.1.4. Quality Manual (QM)

The standard requires the supplier/manufacturer to prepare a quality manual covering the requirements of applicable standard and also requires the quality manual to include or make reference to the quality system procedures and outline the structure of the documentation used in the system.[9]

For a quality manual to be a "manual" it should contain some relevant procedures, working instructions and other supporting documents where seen appropriate, therefore, the quality manual should contain all the policies and practices. The model of quality manual given in ISO/TS 16949 is presented in figure 4.5.

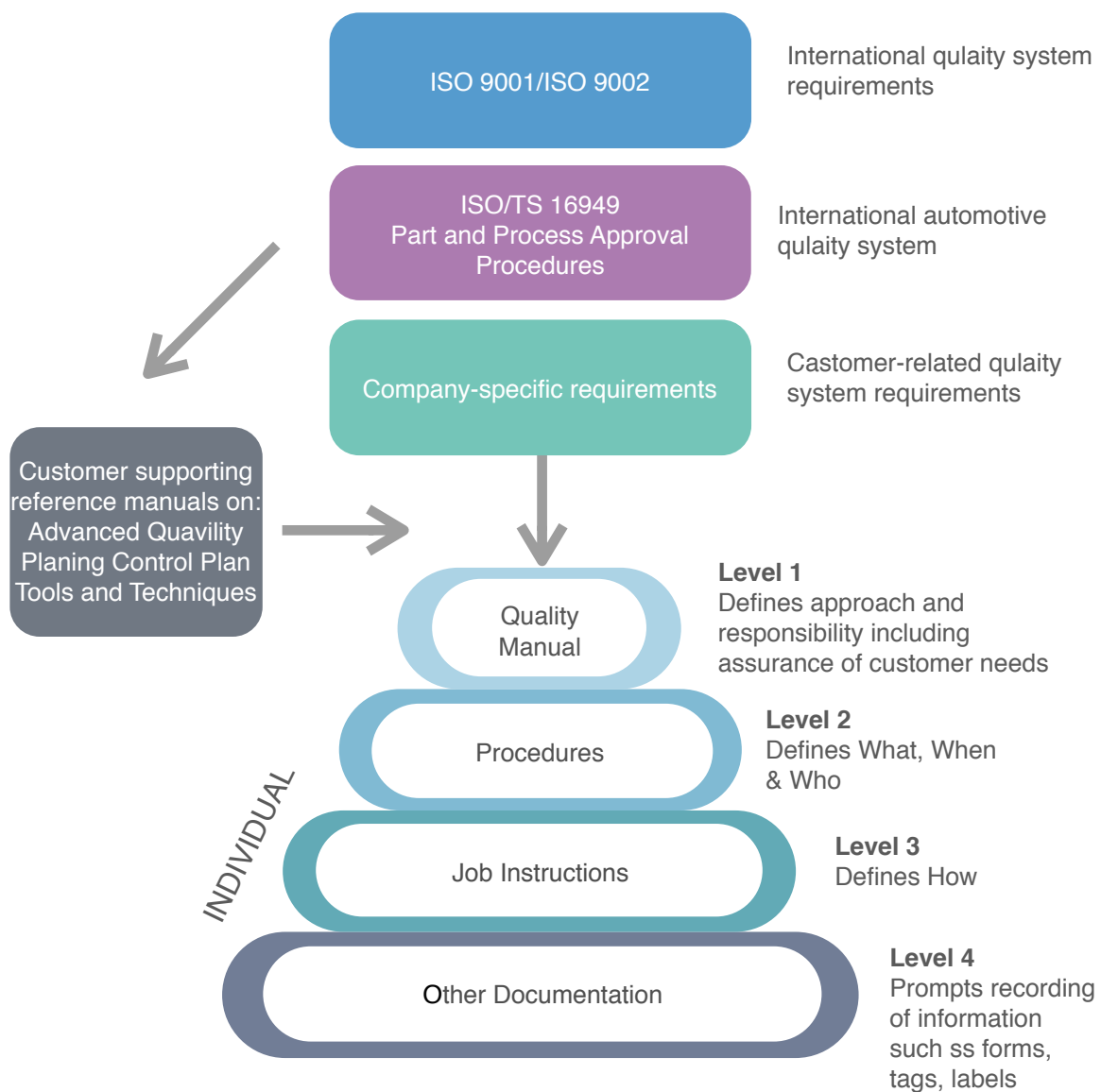


Figure 4.5. Levels of quality systems documentation

Only high-level responsibilities will be defined in the quality manual but most of the responsibilities will be defined in the procedures. The quality manual should not define only an approach, but also the operational policies for implementing the requirements of the standard and for achieving the quality objectives.

Company-specific requirements are not those of suppliers but of specific automakers.

#### ***4.1.5. Type Approval Process in the European Automotive Industry***

Within the European region, two systems of type approval have been in existence for over 20 years. One is based around EC Directives and provides for the approval of whole vehicles, vehicle systems, and separate components. The other is based around United Nations (UN) Regulations (formerly known as UNECE Regulations) and provides for approval of vehicle systems and separate components, but not whole vehicles.

Type approval is the confirmation that production samples of a design will meet specified performance standards. The specification of the product is recorded and only that specification is approved.

Automotive EC Directives and UN Regulations require third party approval or testing where required by the specification, certification and production conformity assessment by an independent body. Each Member State is required to appoint an Approval Authority to issue the approvals and a Technical Service to carry out the testing to the Directives and Regulations. An approval issued by one Authority will be accepted in all the Member States.

##### ***4.1.5.1. European Community Whole Vehicle Type Approval***

European Community (EC) approval of road vehicles is based around a "Whole Vehicle" framework Directive 2007/46/EC and this specifies the range of aspects of the vehicle that must be approved to separate technical Directives. Hence, in order to gain EC whole vehicle approval, a vehicle first will have to be approved for various systems, e.g. brakes, emissions, noise, etc. The issue of the whole vehicle approval does not in itself involve testing, but a production sample of the complete vehicle is inspected to check that its specification matches the specifications contained in all the separate Directive approvals. This certification is

accepted throughout the EU without the need for further testing until a standard is updated or your design changes.

The European approval scheme is based on the concept of 'type approval'. This process provides a mechanism for ensuring that vehicles meet relevant environmental, safety and security standards. Since it is not practical to test every single vehicle produced, one production vehicle is tested as being representative of the 'type'. A number of performance requirements will apply to a given vehicle type, ranging from tires through to exhaust emissions and braking systems. To ensure a consistent approach, the test methodology is outlined in the relevant EC Directive / Regulation or UN Regulation and the tests are carried out at an appropriate facility. Once all of the system and component approvals are in place, the vehicle will be considered as a whole by a designated approval body. When a vehicle is approved, the manufacturer should have processes in place to produce a Certificate of Conformity (CofC) for each manufactured vehicle.

#### ***4.1.5.2 System and Component Type Approval***

The separate technical Directives and Regulations require the approval of individual systems as part of a type of vehicle and some allow for the approval of separate devices. A separate device may be approved either as a Separate Technical Unit (STU), in which case the vehicle, to which it is to be fitted must be declared, or as a component if it can be fitted to any vehicle. System and component approval requires that a sample of the type to be approved is tested by the Technical Service to the requirements of the relevant Directive.

#### ***4.1.5.3. Conformity of Production (CoP)***

Conformity of Production (CoP) is an integral part of the approval process. For each approval it is necessary to declare a manufacturer for the product. This does not necessarily have to be the company that actually manufactures the product but it must be a company that can take, and prove, responsibility for the design and manufacture and hence can control conformity to the type of production samples. It is unlikely that an independent importer could take on the role of manufacturer but it could be the appointed manufacturer's representative for the approval.

Conformity of production requirements are based around established quality systems principles, and certification to ISO9001 may be acceptable as a basis, with appropriate control plans to deal with the specific approval aspects. It may be necessary for Approval Authority assessors to visit the production facility and so it is important to involve Approval authority at an early stage. The complete flow chart of type approval process is shown in figure 4.6.

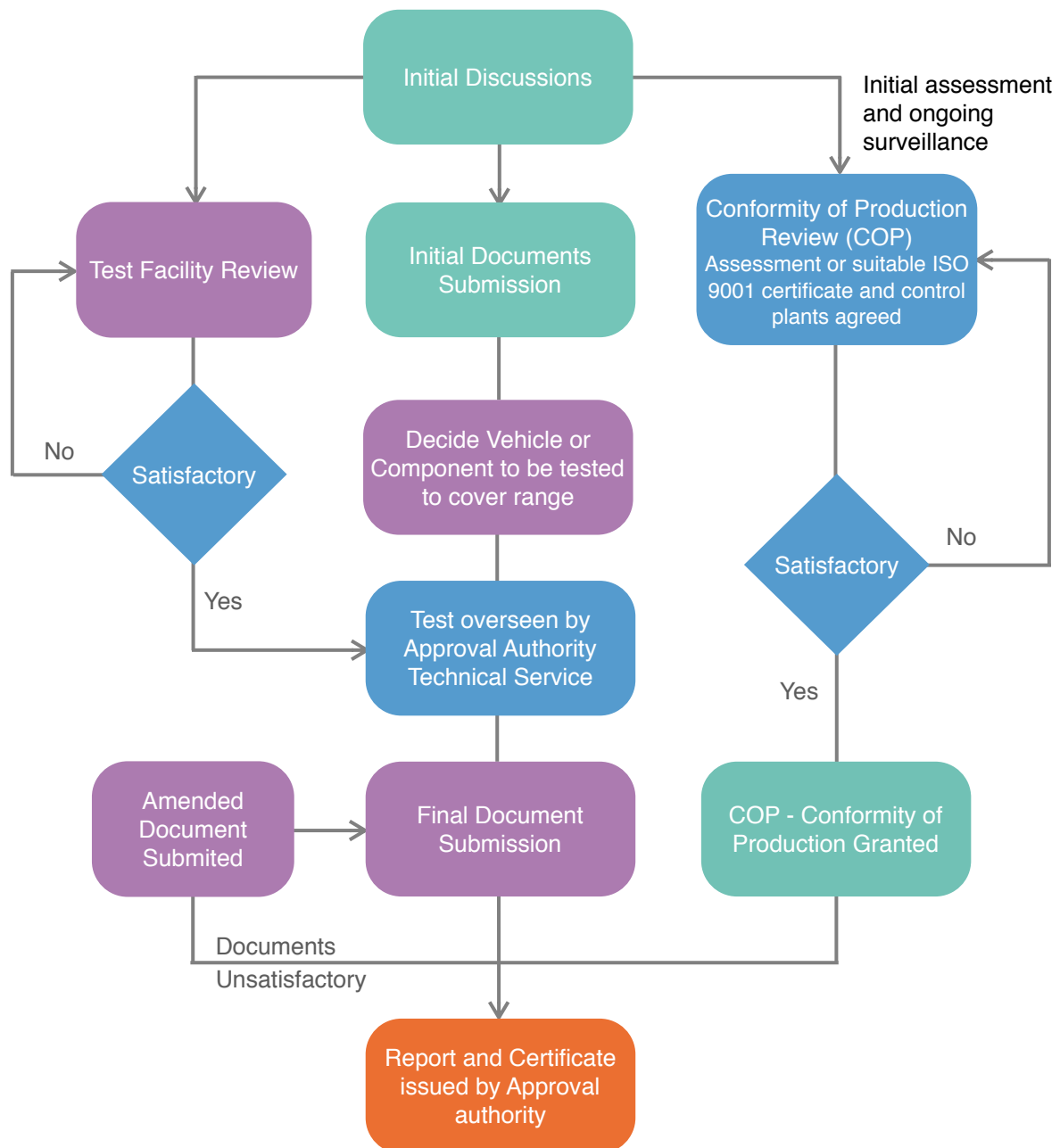


Figure 4.6. Flow chart of Type approval process

#### ***4.1.6. Inspection***

In-line and final inspectors have been an important part of automobile manufacturing for many years. The inspection operators review material, component, and assembly quality to ensure conformance to standards. Data provided by the inspection functions can facilitate product and process improvements to foolproof product quality. The information is used primarily for immediate operator feedback and machine adjustments. This information is used for reports to management for comparison and tracking purposes to support cost justification for machine, product, or process improvements. Management support can be directed to areas requiring improvement based on inspection feedback. This focus can greatly assist management, and the overall process will benefit.

To a considerable extent, the role of inspector in some automobile companies has been taken by production-line operators as a part of the operator process control and product acceptance empowerment mentioned earlier.

The automobile industry has developed a widely accepted classification system (Classification of Defects by Seriousness), with three major groupings for all defects:

- I. Safety or critical functions that can endanger operators or passengers or render the vehicle functionally inoperative, such as brake function, electrical operations, or steering.
- II. Operations that affect primary functions of the vehicle or major appearance items that most customers would not accept, such as inoperative locking mechanisms; faded, chipped, or peeling paint; or noisy operation of engine or brakes.
- III. A third category includes items that do not affect vehicle functions or appearance items not leading to customer complaints, such as crooked labels or stripes, underbody rust, or an inoperative glove box light.

Concerning customer satisfaction, I defects will be returned for repair, II defects normally will be returned, and III defects are almost never returned if they are the only issue found. This severity rating helps automobile companies focus on major issues.



#### ***4.1.6.1. Organization for Inspection.***

Incoming, in-process, and final inspections are the three types commonly used in automobile plants. Inspection methods are usually developed by each group to support customer satisfaction by focusing inspections based on product, process, and operator concerns.

In many cases, formalized procedures requiring documentation must be tracked [e.g., Federal Motor Vehicle Safety Standard (FMVSS) requirements, or other safety items]. Many of these issues can be machine-verified, but issues that cannot be verified are 100 percent checked by inspection personnel. Other inspectors may do random audits of machine processes to verify that machine results and readings are accurate.

*Incoming* checks are performed on raw materials or purchased components. Different testing requirements based on different raw materials must be developed based on hardness, strength, clarity, and other factors.

*In-process* checks include items such as dimensional checks (stampings, machining, molding); equipment temperature, pressure, and timing (casting, forging, molding); fit verifications; and functional verifications. Major functional components such as axles, transmissions, and engines may be operated prior to final assembly to save repair time and costs should a defect be found.

*Final vehicle inspection* is performed after all components are assembled and the vehicle is complete. Many functional checks, adjustments, and verifications are required. Based on vehicle complexity, some additional functional issues may need to be verified. A few of these are:

- Water test: Ensures leak-free vehicles
- Front wheel alignment: Verifies toe, caster, and camber to ensure best handling and long tire wear
- Brake function: Ensuring no leaks and that all components functioning
- Headlight aim
- Complete functional check

## 4.2. Aviation Industry

The aviation industry operates in environments which are highly challenging, due to the varied conditions in which aircraft are operated, such as extremes of temperature and humidity, and the stringent aviation safety requirements which must be met. Therefore, production requirements in the aviation industry are very high and rigorous. Today exist very few aircraft manufacturers worldwide, whose suppliers are from all over the world (Figure 4.7).



Figure 4.7. One example of Boeing's global partners/suppliers[19]

To have an idea about size of the industry on the following figure is shown revenue of the worldwide leading aircraft manufacturers and suppliers in 2014 (figure 4.8), and number of produced aircrafts of two leading worldwide companies - Boeing and Airbus (Figure 4.9).

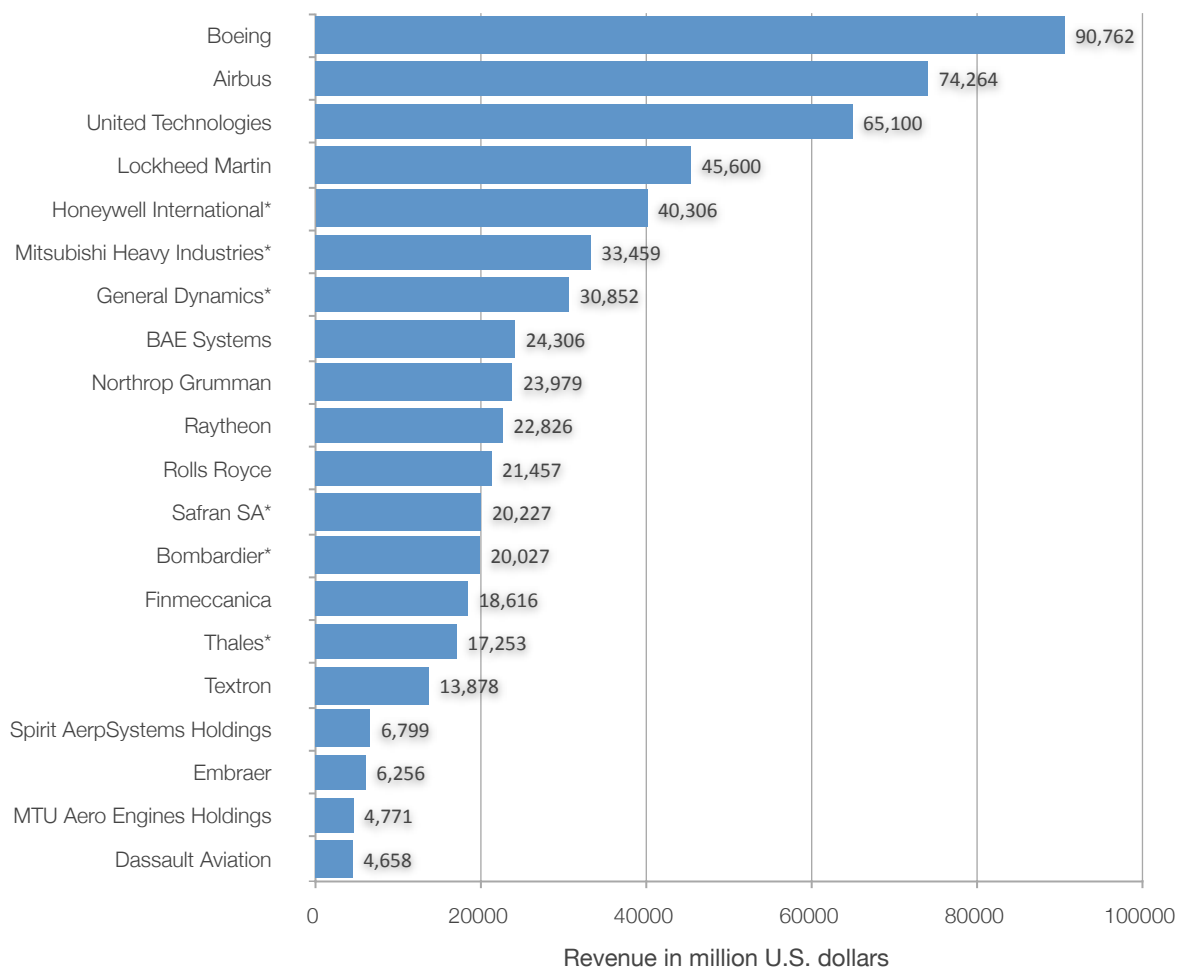


Figure 4.8 Revenue of the worldwide leading aircraft manufacturers and suppliers in 2014 (in million U.S. dollars) [22]

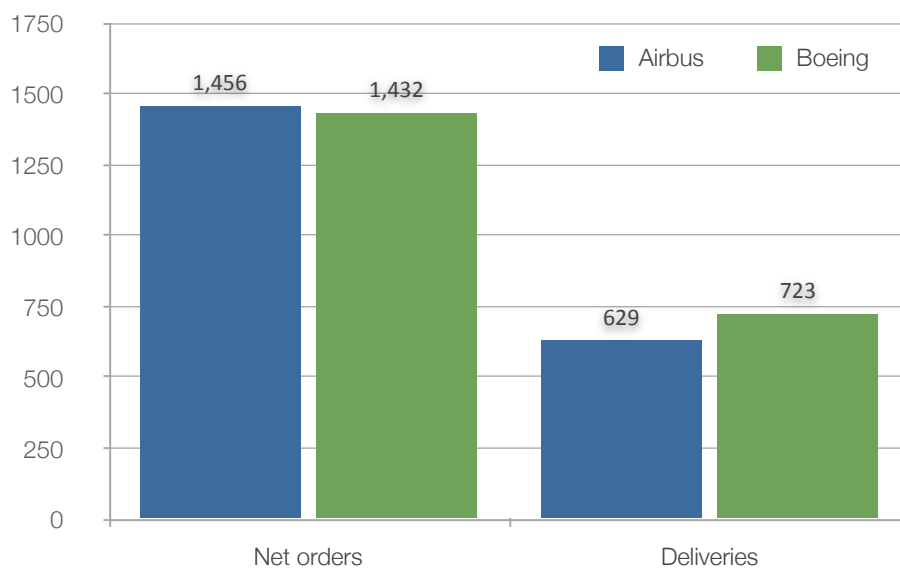


Figure 4.9. Orders and deliveries for Airbus and Boeing in 2014 (in units) [23]

To have an idea about price of aircrafts, on the figure 4.10. is shown average price for Airbus aircraft in 2015. In the figure 4.11 is shown year of 1<sup>st</sup> flight and size of Airbus aircraft for all types. It can be seen that some models of the aircrafts are designed a long time ago and still are in a market today, they improved by new equipments and new engines, but the same model.

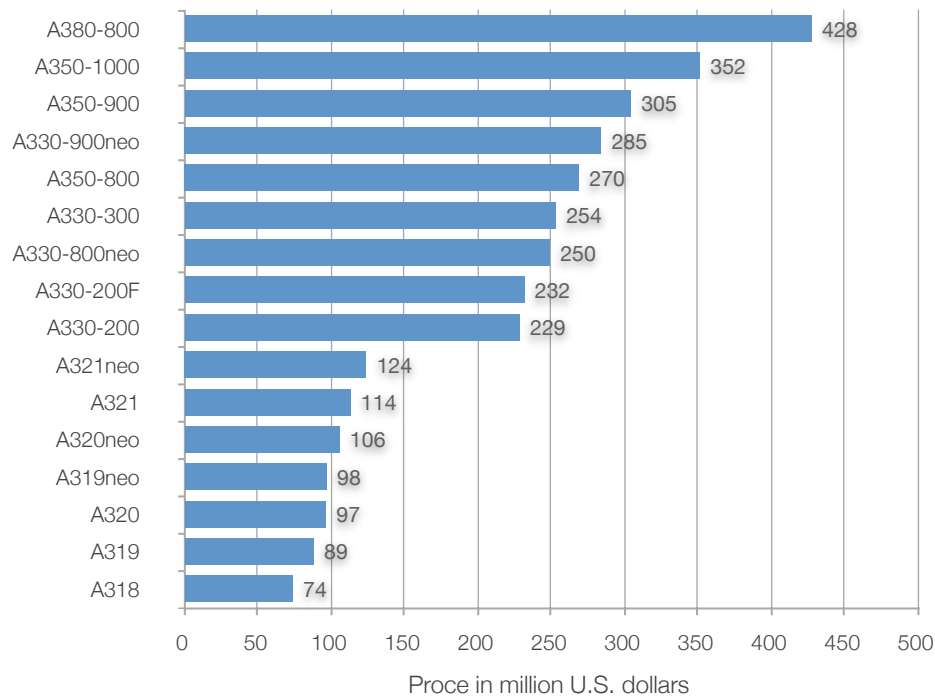


Figure 4.10. Average prices for Airbus aircraft in 2015, by type (in million U.S. dollars)[24]

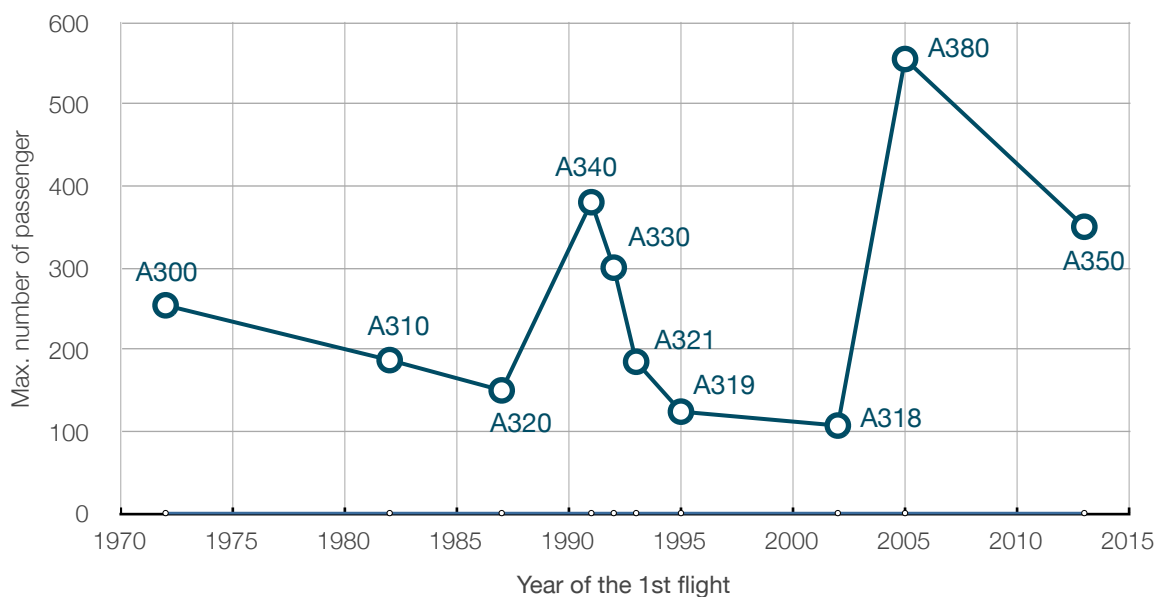


Figure 4.11. Year of a new model launching of Airbus aircrafts and max. number of passenger by type

#### ***4.2.1. Airworthiness and the approvals process in the aviation industry***

The reason why flying is one of the safest means of transportation is the result of decades of experience and research, including after incidents, which have resulted in changes to the designs, manufacturing or maintenance processes employed in the industry. Thus, companies in the aviation industry are highly controlled and regulated by authorities and have to comply with many standardized design requirements, manufacturing and maintenance procedures which contain a high level of stringency.

To respond to these challenges, the aviation industry has used and will need to continue to use high-performance preparations, mixtures and formulations, some of which contain substances which have been placed in Annex XIV of the REACH Regulation 1907/2006 – implemented by the European Chemicals Agency (ECHA) – or which could be placed there in future.

Placing a substance in Annex XIV means that, if no suitable alternatives are available by the ‘sunset date’, the aviation industry will need to seek authorization to continue to use it. To be suitable, alternatives must perform in such a way as to allow the aviation industry to continue to comply with the strict airworthiness standards established by Regulation 216/2008 and its associated Implementing Rules, and they can only be deemed available once they have passed through the extensive approval process by which compliance with this regulation is demonstrated.

Any aircraft must be able to perform safely, with a high level of utilization (~around 16 hours per day), in a severe operational environment, such as [12]:

- sub-zero temperatures at cruise altitude to ground temperatures exceeding 60°C,
- humidity,
- pressure,
- altitude,
- flight loads (including turbulent conditions),
- the possibility of being struck by lightning.

As said above, the aviation industry must comply with the airworthiness requirements derived from EU Regulation No 216/2008 (the document was modified, and the latest version was developed in January 2013 in Europe, creating a regulation No 6/2013) and with similar

airworthiness requirements in all countries where aeronautical products are sold to. All components, from seats and galleys to bolts, equipment, materials and processes incorporated in an aircraft fulfill specific functions and must be, certified, qualified and industrialized. If a substance used in a material, manufacturing process, component, or equipment needs to be changed, this extensive certification process has to be followed in order to be compliant with the airworthiness requirements.

This process requires the cooperation of multiple stakeholders with each having their own responsibilities [12]:

- The airworthiness authority (in the EU: European Aviation Safety Agency - EASA) is responsible for all the issues related to design, in particular, issuing the airworthiness requirements and approving products, parts and appliances under these requirements (such as deliverance of Type Certificates, approval of major aircraft changes and approval of design organizations);
- The Original Equipment Manufacturer (OEM) must comply with aircraft certification requirements and is responsible for issuing instructions for continued airworthiness to be used by maintenance organizations. The OEM is the Type Certificate Applicant or Holder (depending on the certification status);
- The Airline operators must operate and maintain the aircraft per the OEM instructions. They may choose to utilize a Maintenance Repair and Overhaul organizations (MRO) to provide maintenance of aircraft in accordance with approved programs, procedures and processes;
- The suppliers of parts or equipment have to provide OEMs, Airlines and MROs with instructions in conformity with their specifications. These specifications must allow the user to show compliance with the airworthiness requirements.

All components, equipment, materials and processes that incorporated in an aircraft must be qualified, certified and industrialized, in compliance with these processes. Furthermore, if aircraft going to be exported to other countries will have to be certified also by the authority of the “State of Registry” (comparable with ‘flag state ‘ status in the shipping industry).

A representative lifecycle of a typical aircraft product is expected to exceed decades, as illustrated in the following figure for Airbus A300-A310 (Figure 4.12).

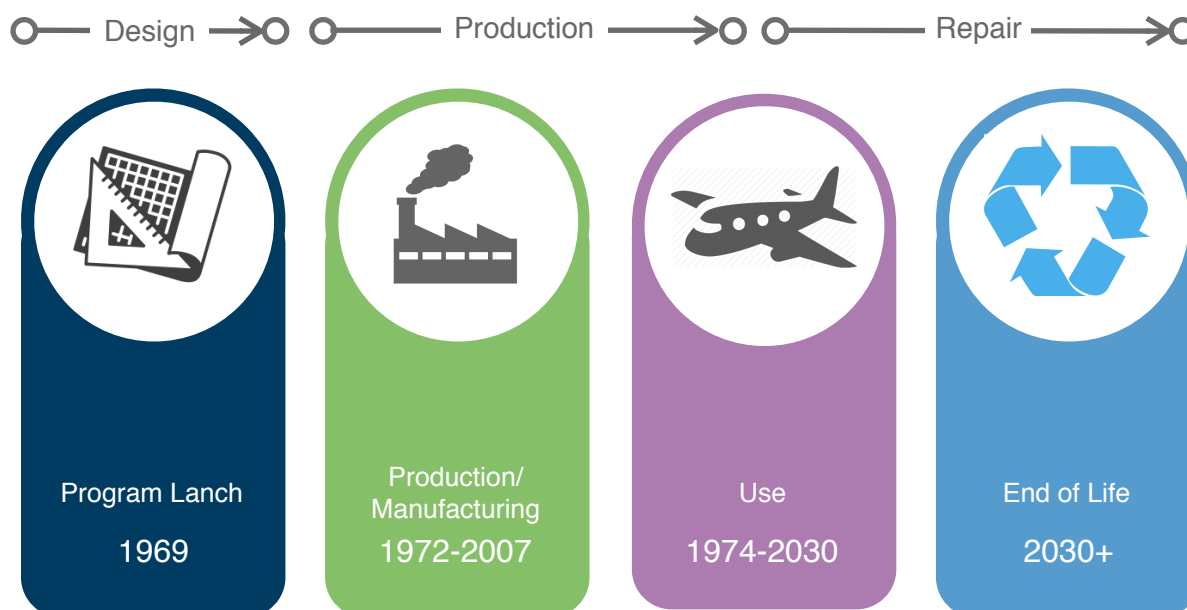


Figure 4.12. Commercial aircraft lifecycle for Airbus A300-310

Some additional key figures when considering life cycle aspects are as follows:

- The development of a new type of aircraft can take up to 15 years.
- The production of one type of aircraft may last more than 50 years
- The lifespan of an aircraft is typically 20-30 years.
- Therefore, typical aircraft categories to be considered in an application are the following:
- Legacy aircraft in operation (the aircraft type is not being produced anymore).
- Operating aircraft of a type which is still in the production portfolio.
- Future aircraft for which a Type Certificate has not been issued yet.

In order to understand the implications of the airworthiness requirements three very important processes are described in the figure 4.13., these processes are certification, qualification and industrialization.

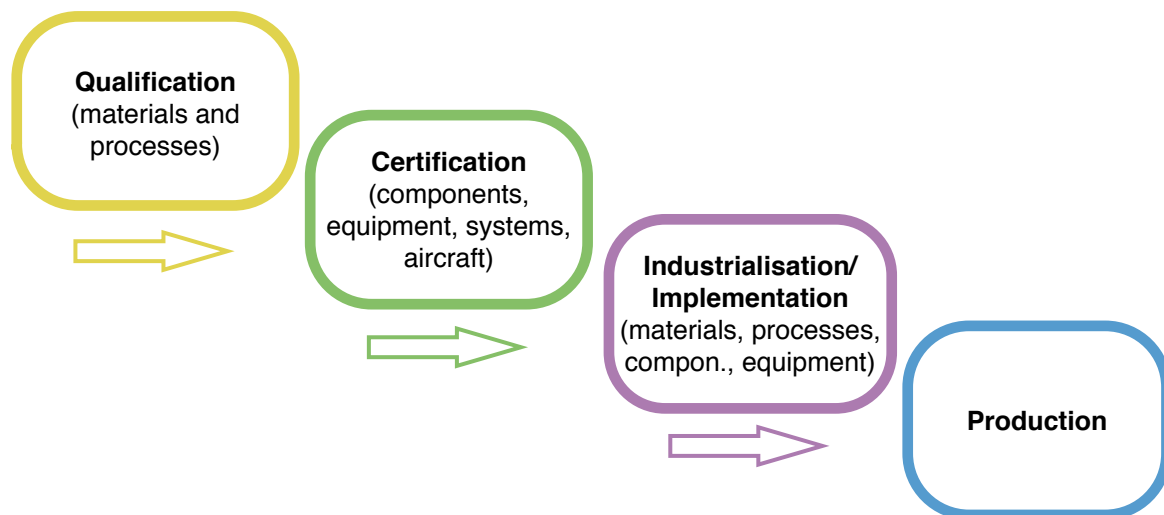


Figure 4.13 Qualification, Certification and Industrialization Process in Aviation industry

*Certification* - is the process under which it is determined that an aircraft, engine, propeller or any other aircraft part or equipment comply with the safety, performance environmental (noise & emissions) and any other requirements contained in the applicable airworthiness regulations, like flammability, corrosion resistance etc. [12]

The airworthiness regulations do not specify materials or substances that have to be used, they set performance specifications to be met (e.g. fire testing protocols, loads to be sustained, damage tolerance, corrosion control, etc.). Based on these performance specifications, the choice of substances to be used either directly in the aircraft or during the manufacturing and maintenance activities are to be defined.

The primary certification of the aircraft (or component of it) is granted to the manufacturer by the Competent Aviation Authority of the “State of Design” which is typically the authority of the state where the manufacturer of the aircraft (or engine or propeller) is officially located (EASA in the case of aircraft designed and manufactured in the EU and European Free Trade Association countries). Aircraft that are exported to other countries will have to be certified (validated) also by the authority of the “State of Registry”. [12]

Manufacturers will work with the certification authorities to develop a comprehensive plan to show that the aircraft meets all of the specified airworthiness requirements. This activity begins during the initial design phase and covers the structure and all systems in normal and specific failure conditions (e.g. tire failure, failure of structural components, hydraulics, electrical or engines). The tests of materials, parts and components of the airplane, up to tests



that include the complete aircraft need to demonstrate compliance. The performance and durability of the various materials have to be confirmed while the behavior of the parts, components and the complete airplane will have to be tested in the applicable environmental and flight conditions including various potential damage or failure conditions. For a new Type Certificate this overall compliance demonstration covers several thousands of individual test plans of which some will require several years to complete. Often, after the initial issuance of the Type Certificate, the tests that have the objective to demonstrate durability of the aircraft during its service life, will continue.

All the different aspects covered by the Type Certificate together define the “approved type design” which includes, among other aspects, all the materials and processes used during manufacturing and maintenance activities. Each individual aircraft has to be produced and maintained in conformity with this approved type design.

Before the new material or design change can be introduced on the aircraft, all test and compliance demonstrations have to be successfully completed and approved by the Competent Authority. This approval results in the issuance of a Supplemental Type Certificate (STC), change approval or repair approval.

To be able to maintain and operate an aircraft the responsible organisations must be approved by the competent authority and compliance is verified on a regular basis. Maintenance of an aircraft requires that the organization complies with specific procedures and materials described in the maintenance manuals which are issued by and the responsibility of the OEMs. [12]

*Qualification* - precedes certification and it is the process where an organisation determines that a material, process, component or equipment have met or exceeded specific performance requirements as documented in a technical standard or specification.

The industry relies upon standards issued by government-accredited bodies, industry or upon company-developed proprietary specs. Most materials and process specifications include either a “Qualified Products List” or “Materials Control” section that identifies products that have met the requirements. OEMs rely upon the expertise of the chemical formulators to provide viable candidates to test against specific material and process specs. Once candidate (s) are developed, the OEM evaluates candidates by performing screening test. If the candidate passes screening, testing is expanded to increase the likelihood that the preparation

will pass qualification. If the candidate fails, which is often the case, material suppliers may choose to reformulate. It is not uncommon to iterate multiple times before a candidate passes screening. In some technically challenging areas, over 100 formulations have been tested with no success.

For those materials that pass screening, production scale-up, development of process control documents, manufacturing site qualifications, and extensive qualification testing is required to demonstrate equivalent or better performance to that which is being replaced. [12]

The industry is ultimately limited by the material formulators' willingness to expend their resources to develop alternative materials and technologies to be tested. Not all material formulators are willing to reformulate their materials to eliminate a specific chemical substance. After initial laboratory testing, each specific application must be reviewed, which means additional testing for specific applications / parts. Airworthiness Certification begins at this same time, this certification can take from 6 months to years. Also it is needed additional time for production scale-up and development of a supply chain. In the following figure 4.14. it is shown an supplier assessment, and also in the figure 4.15. it is shown flow chart of qualification process.

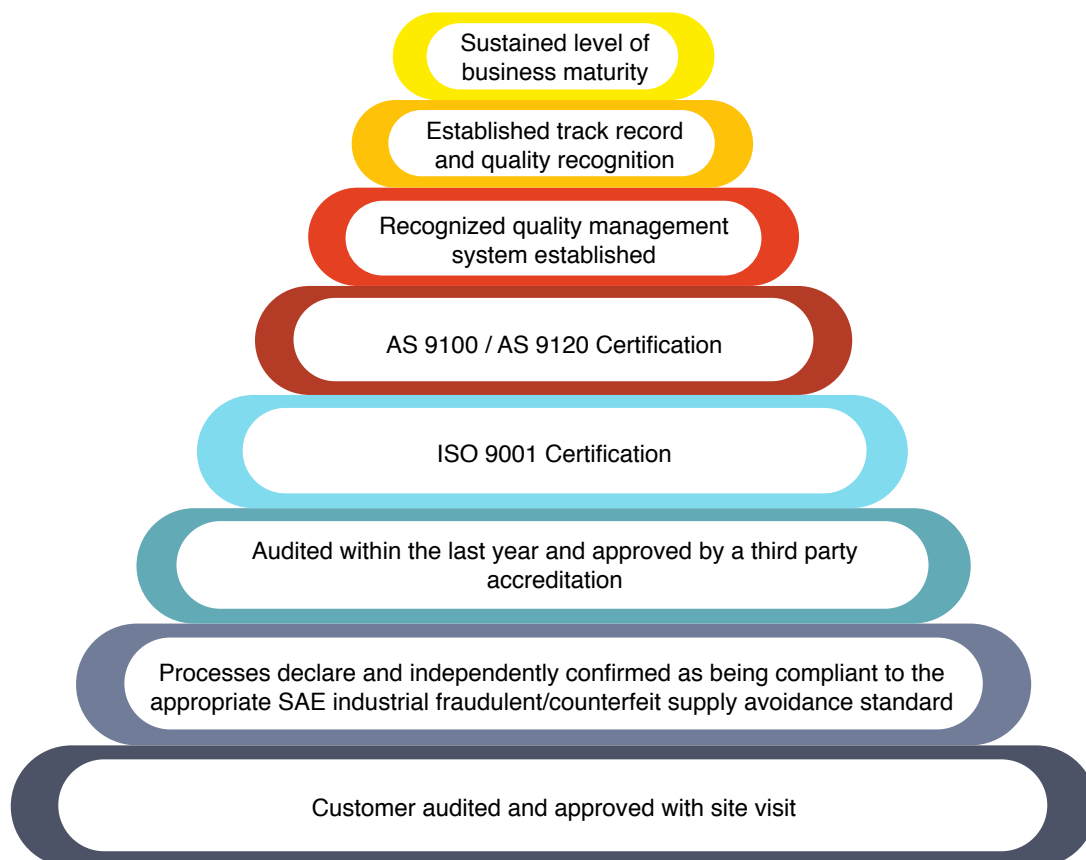


Figure 4.14. Supplier assessment pyramid [12]

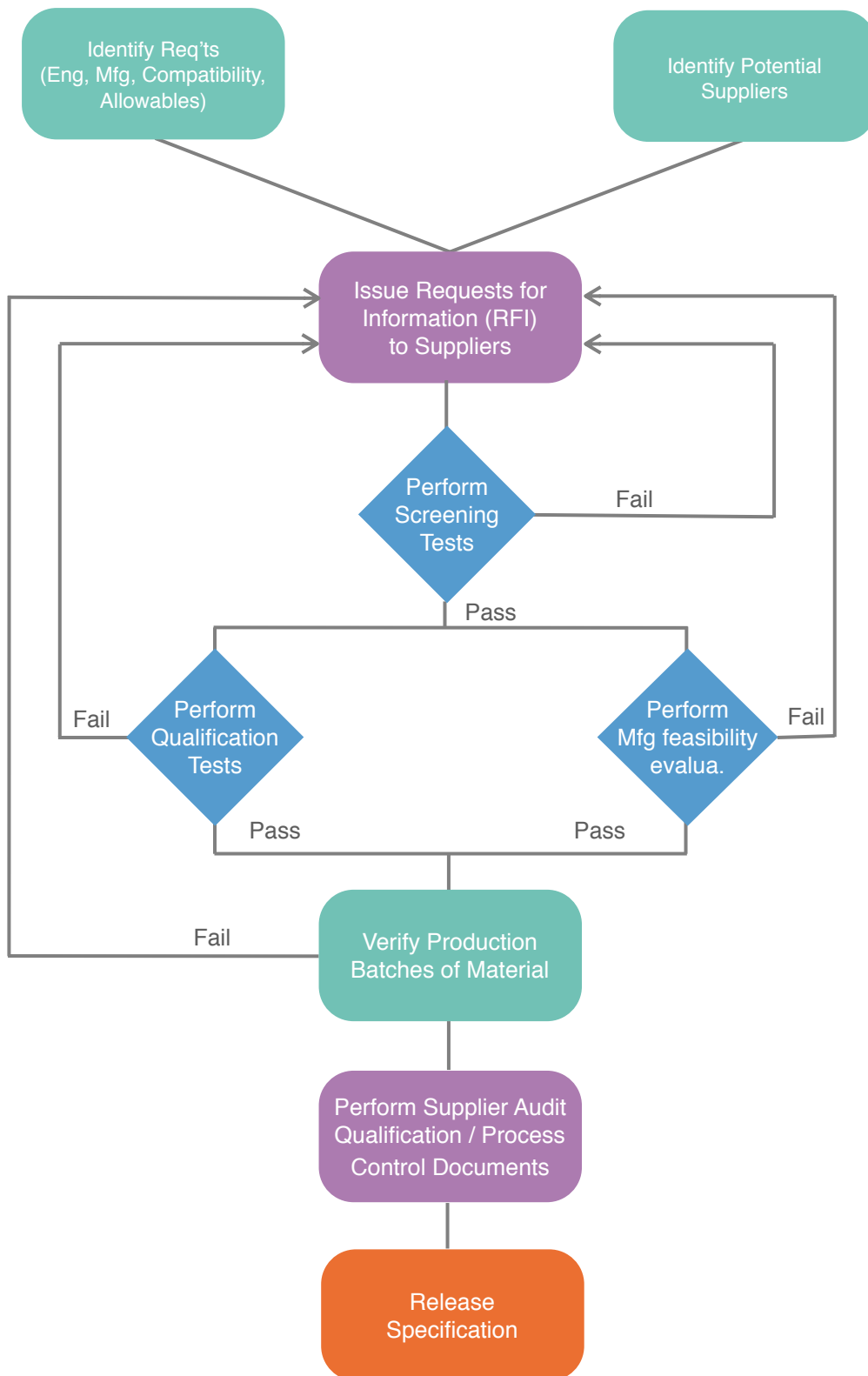


Figure 4.15. Flow chart of Qualification process [12]

*Industrialisation (i.e. the manufacturing)* - is an extensive step-by-step methodology to follow in order to implement a qualified material or process throughout the manufacturing, supply chain and maintenance operations, leading to the final certification of the aerospace product. This includes negotiation with suppliers, investment in process implementation and final audit in order to qualify the processor to the qualified process. [12]

Some special challenges are:

- Low volumes limit influence on changes to suppliers' materials / processes
- Procurement & insertion of new equipment
- Scale-up & certification of new process
- Incompatibility of coatings could be a risk.
- Re-negotiation of long term agreements with suppliers.
- Increased complexity of repairs – Multiple different solutions for different applications as a substitute for a single, robust process.

### 5.3. AS9100 Standard

The dynamic development of the aviation industry has become a motivator to create standards for this sector of the economy, which resulted in building the standards AS 9100 Quality Management Systems-Requirements for Aviation, Space and Defense Organizations. The purpose of this action was to achieve a significant improvement in the quality and safety, and reduce costs by analyzing the values. [11]

Known as AS9100 in North America, EN9100 in Europe and JISQ 9100 in Japan, the standard is strongly supported and adhered to by major aerospace manufacturers including Boeing, Airbus, Bombardier, Pratt & Whitney, Lockheed Martin, Goodrich, Messier-Dowty, Rolls-Royce and many others. It was released for the first time in October, 1999, by the Society of Automotive Engineers (SAE) and the European Association of Aerospace Industries and it was a cooperative effort of the International Aerospace Quality Group (IAQG) and as such, it combines, harmonizes and aligns the requirements outlined in ISO 9001. The standard supplements ISO 9001 by addressing the additional expectations of the aerospace industry. The industry experts who wrote the standard and the representatives who approved it all agree that these additions are essential to ensure product, process and service safety and quality. [10] So far the norm was two renewals to version AS 9100B and the latest one is AS 9100C. Aerospace quality standard AS 9100C relates to the quality management system (QMS) and the requirements for aerospace organization (Figure 4.16).



Figure 4.16 Organisations who create the standard AS9100

This specifies the requirements for a quality system for manufacturing organizations to demonstrate its ability to provide the aviation product meets the requirements of the customer/end user.

Among other benefits, AS9100 has been proved as good practice for complicated manufacturing chains and one of the core benefits is based on the fact that the AS9100 standard is contributing to a more consistent verification method and fewer verification suppliers' audits. The AS9100 standard provides guidance for managing variation when a "key characteristic" is identified. Keys are features of a material, process or part in which the variation has a significant influence on product fit, performance, service life or manufacturability. AS9100 requires that an organization establish and document a configuration management process. Planning product realization is essential for effective and efficient processes. The standard emphasizes planning for in-process verification when a product can't be verified at a later point. Tooling design must also be considered when process control methodology is used to ensure that process data will be captured.[10]

The AS9100 standard includes extensive supplementation in design-and-development functions due to complexity of aerospace products and customers' expectations for reliable performance during a protracted period of time. The European version of AS9100 standard EN9100 provides many of these additions. Both standards cover planning for design-and-development activities and ensuring interim control points during the design process. Design outputs are supplemented to provide identification of key characteristics, and the data essential for the product that will be identified, manufactured, inspected, used and maintained is detailed. Additionally, AS9100 provides information on areas of verification documentation and validating testing and results.[10]

It is undoubtedly a challenge for the industry to manage suppliers throughout the aerospace supply chain. The chain is very long, and within the supply base, there are sources that serve multiple industries. Supplier approval is just one step in the process of managing suppliers.

The standard lists seven specific areas for consideration, they range from clarifying engineering requirements to managing test specimens and right of access to suppliers' facilities. The industry typically relies upon one of three methods for product acceptance:

- An organization might conduct a receiving inspection,
- Perform the inspection at the supplier's facility or
- Formally delegate product acceptance to the supplier.

Procedures for determining the method of supplier control are required, as are the processes used when employing these methods. The most important element of this area of the standard is understanding that a supplier is responsible for managing its own suppliers and sub-tier suppliers. This includes performing special processes that are frequently subcontracted to processing houses. [10]

Manufacturing a product as sophisticated as an airplane or space vehicle requires special attention during the production processes. It's important to ensure that the correct revision of the engineering documentation is being used and documented within the quality documents and that work performance is recorded. Controlling production processes is essential to demonstrate that operations have been correctly performed. Some products require traceability of part or all of their components. This requirement may be imposed by contract, regulatory agency or internal needs. In any case, AS9100 standard provides the essentials of an effective traceability program.[10] The aviation standard AS9100 is the norm, but due to its nature it is also necessary of taking care of safety and high quality of the products. Quality management system that is based on AS9100 standard is complex but also largely provide high quality and safety of aeronautical products.





## **5. STRATEGIC OUTLOOK-INNOVATION IN BUSINESS ASSURANCE LEADING TO NEW APPROACH**

### **5.1 Comparison of Marine Supply Industry and Other Industries**

Before starting to explain main differences between industries it is very important to point out what make maritime industry unique in comparing to any other industry. One of the unique difference is definitely that in maritime industry we have single (one by one) production of final product (ships, offshore structure etc.) in more than 95%.

Second major difference is that classification societies do not exist in any other industries. As previously explained in chapter 3, classification societies are with some exceptions non-governmental organization that establishes and maintains technical standards, i.e. rules and regulations for the design and construction of ships and Oil&Gas installations. CSs validate that the design and construction is according to their rules and regulations and carry out regular surveys during the manufacture and later in service to ensure compliance with these standards.

The Third major difference is in the process of production of a new ship. Where the automotive and aviation industry) mostly can be considered a mass/ serial production, the development and acceptance into production of new products (e.g. new car or new aircraft) starts before production itself and usually takes between 3 and 7 years depending of product complexity. In the development phase they will do and approve the complete design and all components and equipment, build prototype and do all product testing. Finally they will approve the product and launch serial production (Figure 5.1).

In the ship building industry development of a new product is quite different, because on the beginning there is a customer (shipowner), and the design and ship development follows the customer's specifications according to the size and ship sector specific. Usually, production period of a ship (from initial design phase to the delivery of a ship) is in maximum but normally less than two to three years and in that period have to be done all design, testing, production, approvals and final sea trials (Figure 5.2). It can be seen that there is no prototype

for testing, and a first verification will be done to meet the design criteria are done in a model test using model test basin. First real tests of the overall Product, i.e. the ship will be done on a series of sea trails before delivery.

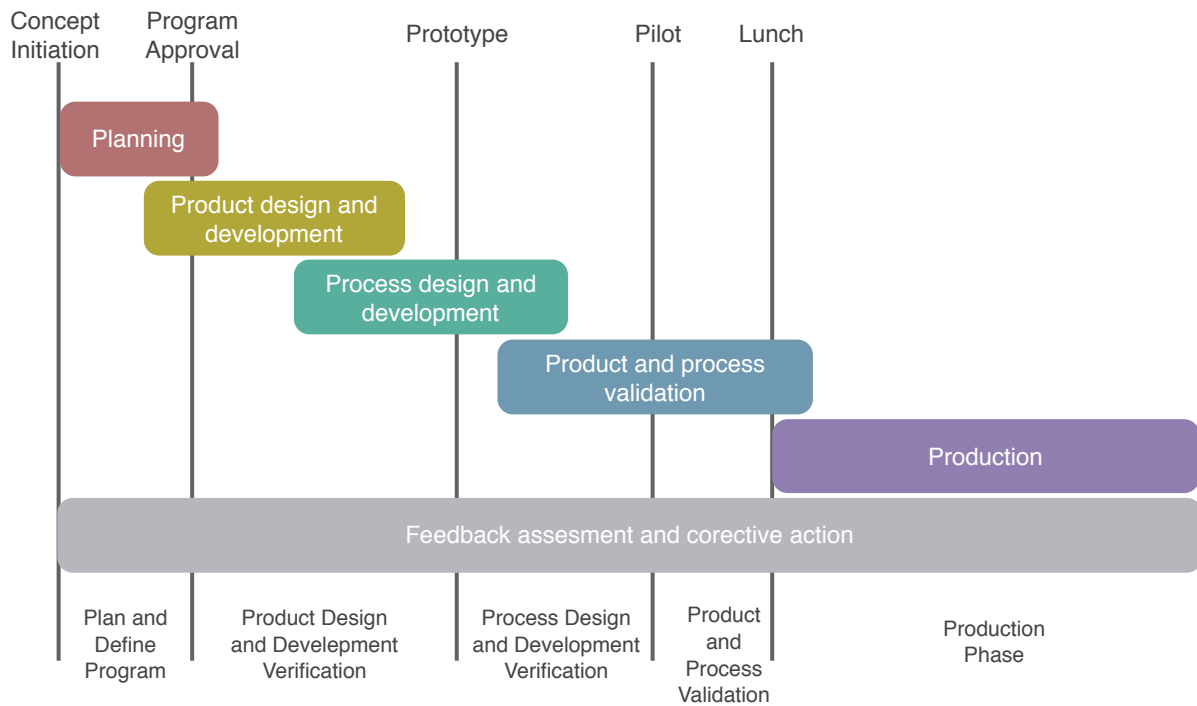


Figure 5.1. New product development phases for serial production

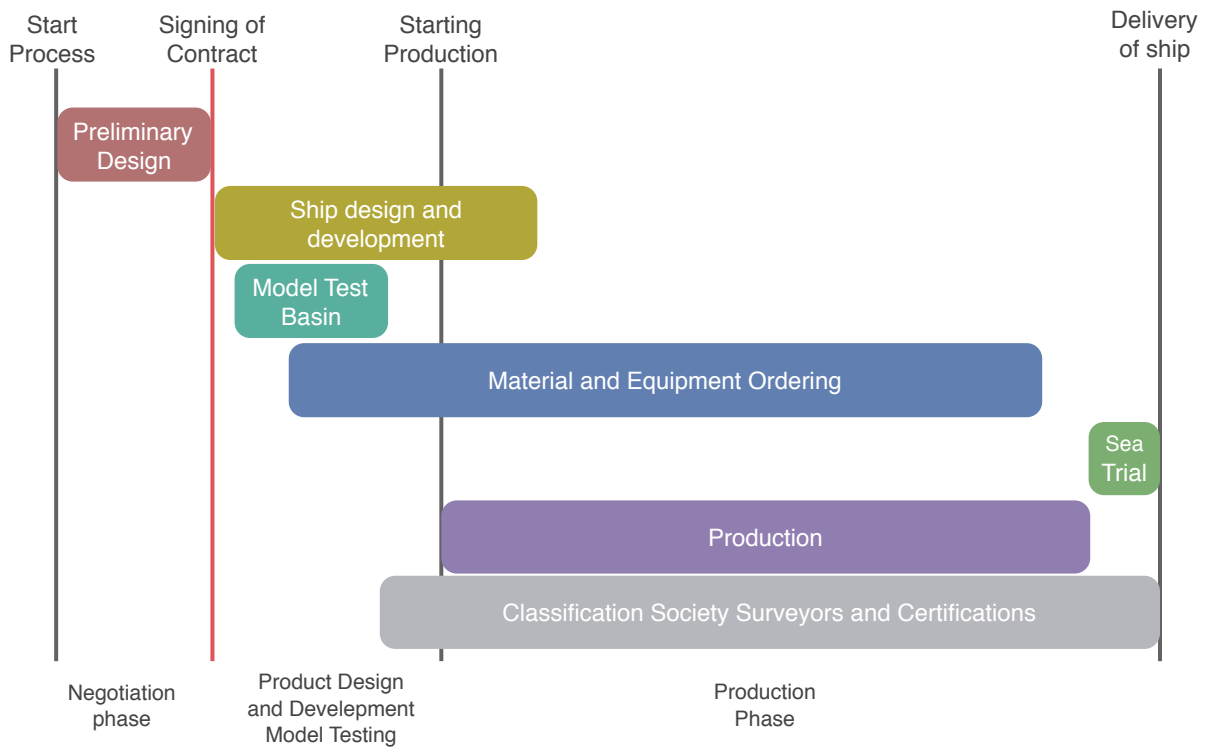


Figure 5.2. New product development and production phases in shipbuilding industry

In the following diagram (figure 5.3) the main stakeholder parties in the shipbuilding industry are shown. A ship manufacturer is a shipyard that build ships or some other offshore structures. Another important body is the marine supplies industries for materials, equipment, components and systems. The shipyard normally purchases all systems and components from the supply industry. It can be seen that most of stakeholder activities are connected with services offered by Classification Societies. The Design office can be part of the shipyard or it can be as a separate contracted design house. The marine supplies industry has also their own design departments but they don't share design of equipment or component with the shipyard or design agent, as they mainly send the design documents and technical files to the through the shipyard contracted Classification Society of their or the end users choice for review and final approval.

Model basin is separated company that carry out all necessary tests ordered from a shipyard or a design agent.

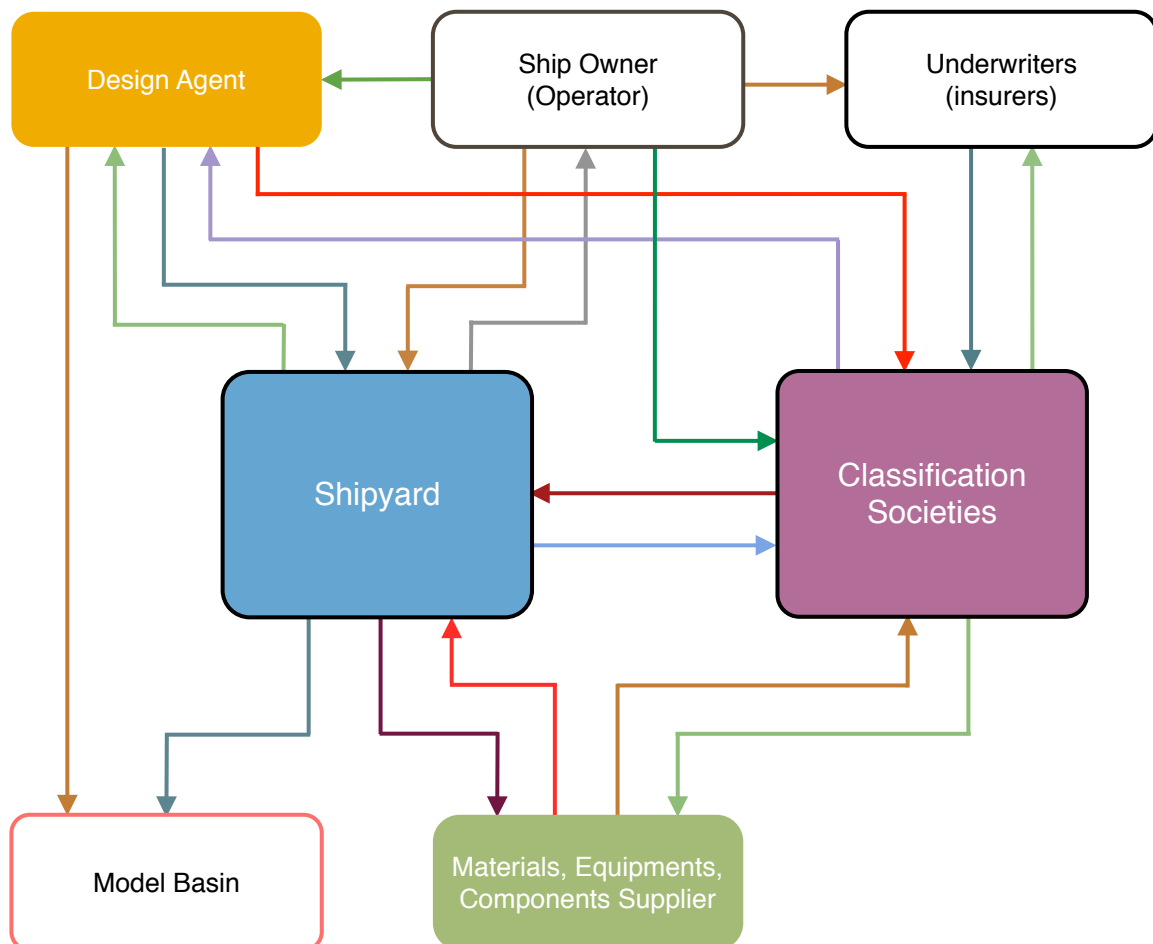


Figure 5.3. Main bodies and actors in shipbuilding industry

In other two industries (automotive and aviation industry) there are similar bodies but with different relation as can be seen in diagram below (figure 5.4). First very important point is that an owner is not related with design department in a developing phase. Manufacturer's design department is in very strong connection with supplier's design department in both industries (automotive and aviation industry). Usually, manufacturer's design department following all design of components in supplier's design department.

The approval body for a design and product certification in aviation and automotive are acting as government owned department, for aviation industry it is whole organisation (eg. EASA in EU) that is responsible for many issues. In aviation industry this organisation will issue a certificate of airworthiness unlike in shipbuilding industry classification societies don't issue such a certificate. Only responsible person for seaworthiness in maritime industry, between many players, is a ship owner.

In both of these, the other mentioned industries, there is no connection between an insurers and organisation responsible for approval.

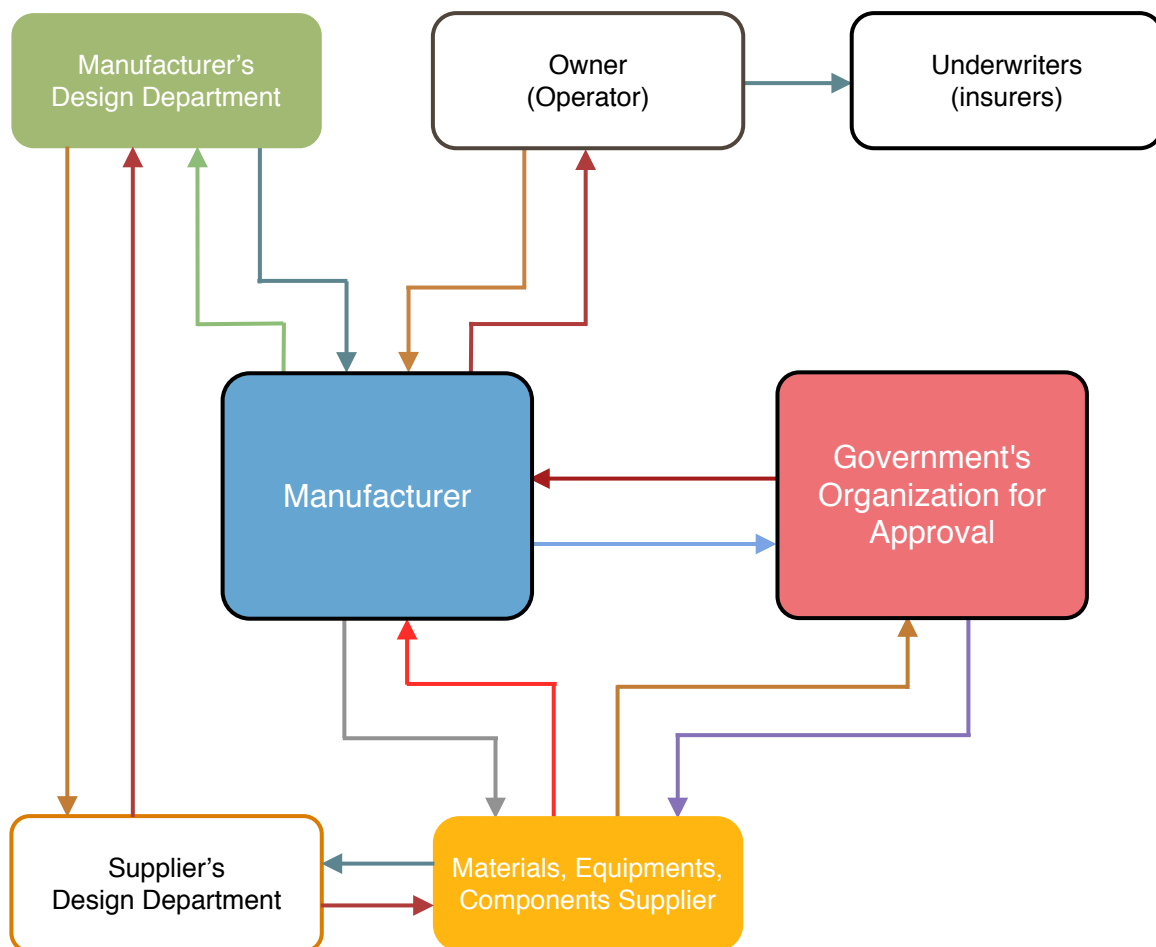


Figure 5.4. Main bodies and actors in automotive and aviation industry

*Automotive industry* - has different supply chain structures from the shipbuilding/marine industry and major difference is in the number of final producers, where there are around 50 European shipyards and more than 1000 in the world, and there are around 65 international car makers in the world, but the automotive industry is highly consolidated and a handful of major corporations own nearly all of the world's major car brands (Figure 5.5).



Figure 5.5. Few of major corporations own nearly all of the world's major car brands [17]

In automotive industry there is oligopoly of very few big car makers and they actually decide on the rules and the certification process for suppliers, therefore, it is very easy for them to harmonize their requirements into a one globally oriented standard like TS 16949.

In the automotive industry we have a lot of carmakers with very different requirements and quality related aspects applied to production which eventually results in different perception of the end product by the end users, for example, the level of quality and reliability of the Mercedes, BMW or AUDI is perceived higher than for the Fiat or Hyundai. The customer selects the car manufacturers that best fit its requirements in terms of quality and safety but each automaker must comply with the minimum requirements in terms of quality and safety, which is defined by government regulations.

Similarly, in the shipbuilding industry, we generally do not have the brand of a ship like in automotive industry, usually shipyards can produce a ship to different quality related requirements. A customer chooses a level of quality and safety related control in a way to select a classification society of his choice. As Classification societies don't have the same expertise and set of requirements for all different ship sectors, by selecting a specific classification society a vessel will be built according to those rules which will ultimately result in a certain level of quality and safety. All this applies also to the marine supply industry in the production of materials, components or equipment. The only difference is, that carmakers specifies the requirements in terms of quality and safety, and he is involved in product design, as well as in the manufacturing process, therefore, he has almost all information about the product, which leads to a permanent increase in the quality assurance, and therefore time and cost also. Recently, carmakers are trying to involve its major suppliers in the phase of design and product development, so that they can better understand their requirements, and also by their experiences perhaps improve the process.

In the marine industry classification societies and their service departments are looking at the final product by stating compliance with the rules requirements, without necessarily going into each of the the production processes. This practice is changing today as driven by the marine stakeholders into a more quality assurance scheme based survey intervention, which is following other best practices and product lifecycle management (PLM) principles adopting industries.

However, classification societies are not designers, and also not getting involved in the development of the production processes. To work on principles of manufacturing process related quality assurance means however to look into the manufacturing processes rather than the final product, which implies a very good understanding of the production process itself. Therefore, classification societies in the future will need more system/process auditors with a

broad background, i.e. qualified staff who understands the specific of the production's processes.

Aviation industry - must comply with the airworthiness requirements derived from a national aviation authority. All components, equipment, materials and processes incorporated in an aircraft must fulfill specific functions and must be, certified, qualified and industrialized. This means that suppliers have to meet very rigorous requirements in terms of quality assurance. As the requirements for suppliers are very rigorous, supply industry is usually globally to follow the same requirements. Therefore, only a limited number of suppliers of these components and equipment are able to take leading positions in the aviation supply industry. In the aviation industry there is a strong need for harmonization of requirements which in practice is secured through the development of a common, i.e. harmonized standard.

Compared with the marine industry, the aviation industry has only one kind of "classification society" acting at national level. These organizations are very aligned and each acting on its territory (e.g. FFA for US, EASA for EU and JIT for Japan) and they are not in competition to each other. This is one of the key differences between these two industries, where in the marine industry have more classification societies which are not operating at national but international level. In aviation manufacturers need to work with those authorities to develop a comprehensive plan to show that the aircraft meets all of the specified airworthiness requirements. This activity begins during the initial design phase and covers the structure and all systems in normal and specific failure conditions (e.g. tire failure, failure of structural components, hydraulics, electrical or engines). At the end a prototype of a product will be rigorously tested, and if it meet all requirements, the airworthiness certificate will be issued. In the following table is presented comparison between marine, automotive and aviation industries (table 5.1).

Table 5.1. Comparison between different industries

	<b>Marine Industry</b>	<b>Automotive Industry</b>	<b>Aviation Industry</b>
Single Production of parts	✓	✗	✗
Serial/Mass Production of parts	✓	✓ ✓ ✓	✓ ✓
Inspection based on Quality Assurance scheme	✓	✓ ✓ ✓	✓ ✓ ✓
Number of final manufacturers in EU	~50	~15	~5
Setting the requirements of QA	Classification Society	<i>Manufacturer</i>	<i>Manufacturer</i>
Responsible for Design approval	Classification Society	Government's organization	Government's organization
Division of the parts based on safety or importance	✓	✓ ✓	✓ ✓ ✓
Has industry specific standard	✗	✓ ✓	✓
Traceability of parts performed by	<i>Serial number, Certificate number</i>	<i>Serial numb., barcode, 2D barcode, RFID</i>	<i>Serial numb., barcode, 2D barcode, RFID</i>
Manufacturer involved in design development of components with suppliers	✗	✓ ✓	✓
Brand name of components installed in final product appears visible	✓ ✓ ✓	✗	✓
Time period required for development of a new product	~1 year	3-5 years	4-7 years
Time period for production series of products or a single products	1-3 years ( <i>single</i> )	4-7 years ( <i>series</i> )	20-30 years ( <i>series</i> )
Level of product complexity	✓ ✓	✓	✓ ✓ ✓



### **5.3. Some Possible New Direction for QA Certification Scheme**

Today, industries tend to change the strategic production, where the time of delivery is very short and where are applied new forms of production - smart automated manufacturing. Such changes in the production necessarily requires the changing methods of product quality assurance. Marine industry also follows these trends and Classification Society as an organization responsible for product certification shall accompany these changes with new methods that will follow needs of industry.

Quality Assurance Schemes appear as very good improvement over traditional, i.e. direct survey arrangements. Switching to QA schemes the applying company will have greater flexibility in their certification process, especially if the company produces a complete product without having subcontractors involved. However, if there are sub-contractors who have no QA based certification process, it reduces the effectiveness of this method, because they are obliged to follow the traditional direct survey.

Another problem which occurs with QA schemes is that a number of annual audits are required if the manufacturer operates QA schemes with several classification societies. Namely, QA based certification involves two or three times the annual audit of the manufacturer, which doesn't relate to the number of manufactured products and adds no value for the manufacturer. Many companies have one or more approvals with several classification societies. Annually each of classification societies would perform 2 or 3 times the audit in one certification cycle.. Besides the additional costs for audits this may also generate cost for stopping production due to the audit process. It is obvious that this option will not be suitable for all companies, and this is one reason that some manufacturers will continue to keep the traditional way of certification (direct survey). The economy of scale consideration need to be carefully reviewed and a case by case decision has to be made between the certifier and manufacturer of the component or equipment.

Multitude certification is one of the main problems of marine supplies industry, especially for small suppliers. As explained in the chapter 3, one of the solution is definitely EU Mutual Recognition Type Approval Certificate, but critical systems cannot be accepted under Mutual Recognition arrangements for safety reasons as specified therein. The scope for Mutual

Recognition has been limited to the group of equipment described under level 3 of the safety pyramid (see figure 3.4).

By looking in this direction of EU mutual recognition agreements, it can be extension in such way to divide parts of a product based on criticality and safety by using some risk modeling approaches. Using risk modeling it can be defined which parts are classified safety critical, less important and some which are not important regarding the criticality (figure 5.7). Some critical product like an main engine doesn't contain all parts as very critical, there are a lot of parts that are non-critical or less critical. Classification's rules from different Class Societies, regarding such non-critical parts, are very similar, almost the same. Thus, there is no reason to not accept those parts between CSs.

Another option could be, instead of looking at individual parts, it can be considered looking after the manufacturing processes. At this moment none of the classification societies have rules related to the processes. Therefore, it is very easy to adopt common procedures for all classification societies, on the basis of EU mutual recognition agreements. The manufacturer using exactly the same processes when produces for any classification society, and all classification societies will annually audit exactly the same process.

A Manufacturer will apply and obtain a QA based certificate from different classification societies and all Classes will initially audit the manufacturer and issue the certificate, but annual audit of a manufacturer from one classification society would be acceptable to all others. This will reduce number of annually inspection, without compromising the safety.

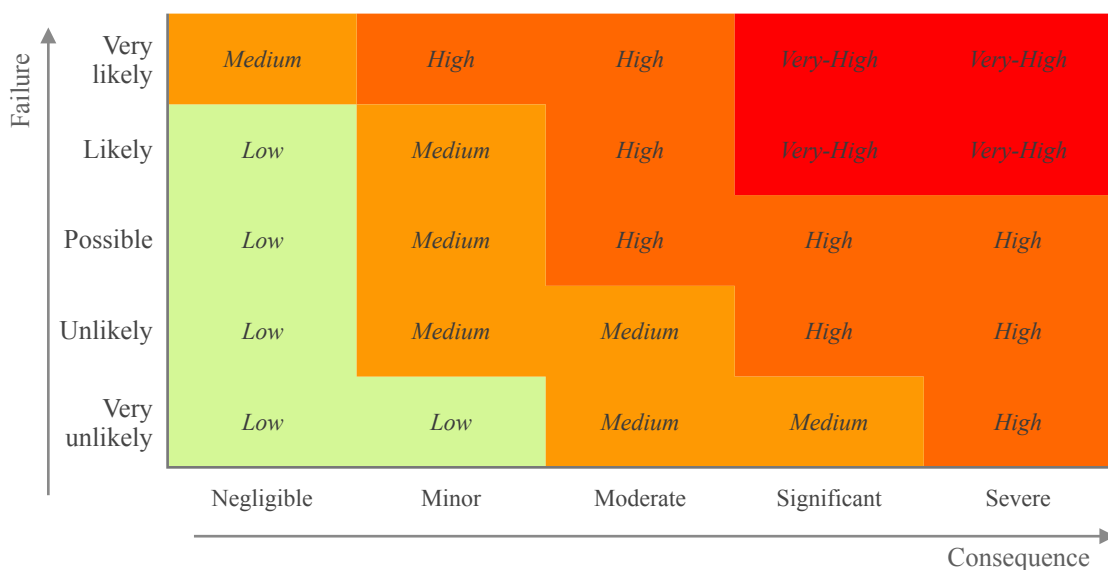


Figure 5.7. Risk assessment matrix for the criticality impact of parts

## **5.4. Product Marking by Using RFID Technology**

### ***5.4.1. Introduction***

Traceability of Products is a very important issue within the scope of quality assurance in general and especially important in the marine supply industry as the majority of marine and offshore installations are mobile and globally distributed during their lifetimes.

This applies equally for marine equipment subject to certification by Classification Societies (CSs). The process of a Classification Society requires to trace all components during periodical audits, maintenance processes and if required re-placements, i.e. repairs or conversions to confirm compliance with class rules or any other regulatory requirements.

Until now, in the marine supply industry, traceability of parts is based on mechanical marking of parts with numbers, e.g. unique identification, batch or heat number as required by the agreed marking specification where available or the class rules. There are other marking requirements stipulated in related regulations like the ‘Wheel mark’ used in statutory product certification under the Marine Equipment Directive Regulation.

As traceability of products and their approval status is essential this has been considered as an area if introducing new technology available in product marking applied also to the marine industry.

RFID technology is well known and practiced in different forms for a very long time in other industries, and this chapter is intended to be a very basic analysis of how RFID technology will fit the purpose by using in marine supply industry, as well as in maritime industry.

By increasing traceability of parts and components in marine industry, Classification Societies are challenged to simplify their inspection and/or auditing processes, where RFID technology could contribute. To apply consistently RFID on marine equipment could improve traceability of safety critical products for all stakeholders involved in the construction and operation of marine installations like ship builders and equipment suppliers. Another important aspect is to help to prevent counterfeit assets entering the market. On the other hand, product tracking and traceability in a factory environment is of vital importance to any manufacturing company. Ensuring that all parts leaving the production line have been machined with no defects is a requirement that more and more companies wish to reach this level. A factory without product tracking and traceability system in place or by using an unreliable system,

would inevitably face the risk of having products leaving the factory with undetected defects. Thus, by introduction of radio frequency identification technology (RFID) to product marking can be a huge benefit for maritime industry (Classifications, shipowners, shipbuilders and equipment suppliers alongside the supply chain).

#### 5.4.2. Development of RFID Technology

Automatic identification RFID has been in commercial use since the early 1970's. The earliest RFID was used to prevent theft, control access, and identify livestock. While those methods are still being applied today, many more applications have since evolved. The technology has become more refined and the data more reliable resulting in increased quality and leaner processes. Private and public corporations, small-medium size businesses, and governments around the globe have concluded that RFID is capable of providing the needed vision into their process. These diverse organizations, by revenue and application, have proven that the benefits of RFID are quantifiable.

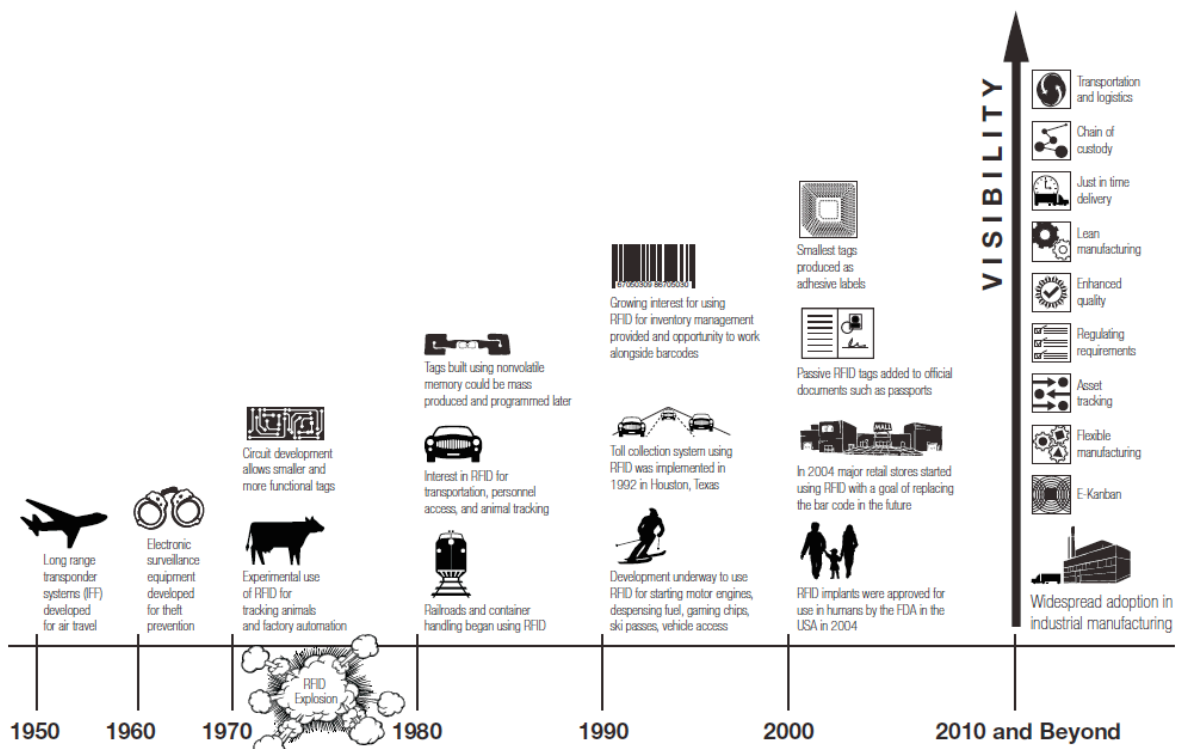


Figure 5.3. RFID technology evolution[20]

In a recent study by ABI Research<sup>1</sup> “The market for RFID transponders, readers, software, and services will generate \$70.5 billion from 2012 to the end of 2017. The market was boosted by a growth of \$900 million in 2011 and the market is expected to grow 20% per annum. The number of applications that utilize RFID technology is growing rapidly. The past and projected growth indicates the technology is meeting the needs of multiple sectors of industry all over the globe. [20]

Electronic passport - RFID based e-passports have been introduced in many countries, including all the European Member States. Each e-passport contains personal data and a digital photo of the owner. The second generation of e-passports include also fingerprints. There is an opinion that RFID technology can be easily falsified and this example of e-passports shows how RFID technology can be very safe and secured. There are many highly secure way to secure data in the memory of RFID against counterfeiting.

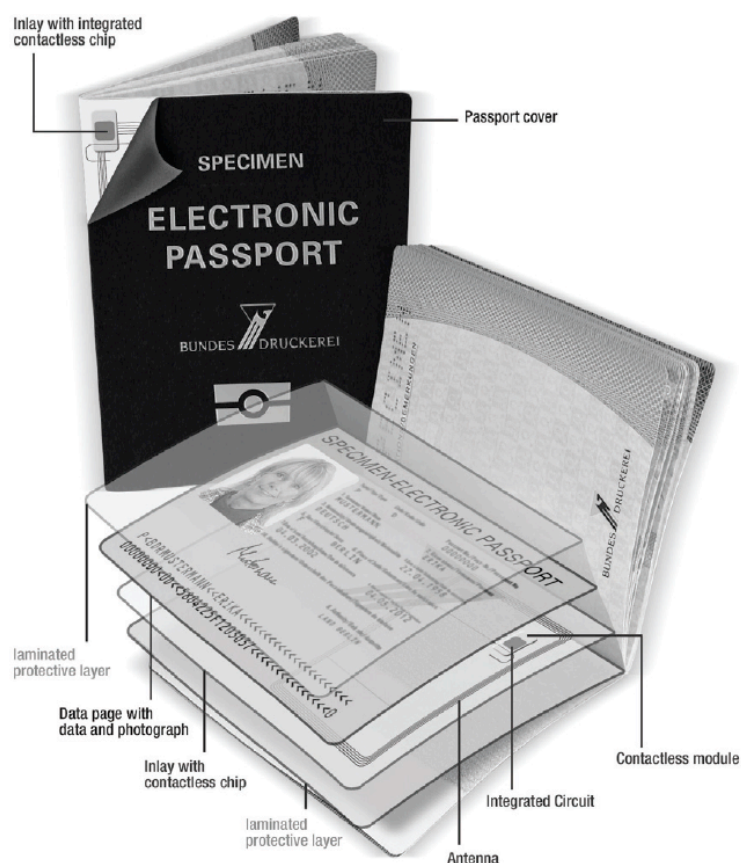


Figure 5.5. The electronic passport with RFID tag [21]

### ***5.4.3. The Usage of RFID Technology in Others Industries***

#### *Aerospace applications*

The part marking and tracking initiative in the aviation industry, called SPEC 2000, is designed to improve component traceability and air safety, while reducing maintenance costs. Sponsored by the Air Transport Association, SPEC 2000 sets information standards for parts and repair services for commercial and civilian aircraft. SPEC 2000 has the support of the Federal Aviation Administration and Europe's Joint Aviation Authorities.

The move to require that each critical part on a commercial plane be marked with its own individual identification number is supported by the world's largest airframe manufacturers and engine builders. More recently, Radio Frequency Identification (RFID) is generally applied to the use of special integrated circuits which contain data that can be electronically read from a distance without direct line of site.

The requirements for RFID tags to be used in the aviation industry are very different from non-aviation uses. The parts identified by the RFID tags are high value items, which are often used for ten years or more. Reading and writing across a moderate distance, and over the life-spans of these tagged-parts, is expected to fulfill the promise of data automation for accuracy and cost savings. Furthermore, the aerospace industry is subject to unique considerations regarding qualification, regulations, and safety, which are enforced by national authorities such as the FAA, EASA, FCC, etc.

#### *Automotive applications*

Automotive manufacturers are searching for ways to actively track parts through the supply chain from supplier through assembly and delivery to the customer. The AIAG B-11 standard, the first RFID standard in the world for item-level traceability, provides a tool that can assist car and tire manufacturers and tire retailers in documenting the genealogy of tires throughout production, assembly and distribution. The B-11 standard also provides a useful technology tool to help automakers and retailers streamline their respective supply chains through increased real-time visibility of their parts and processes.

#### 5.4.4. RFID Technology Background

Non-optical Technology RFID is a flexible technology suited for parts traceability applications. Most of innovative applications designed for RFID system can be divided into few classes such as asset management, tracking, authenticity verification, matching, process control, access control, automated payment and supply chain management.

RFID can be supplied as read-only or read/write and does not require contact or line-of-sight to be used, can function under a variety of environmental conditions. RFID uses a reader and special RFID devices (e.g. tags, inserts, etc.) and uses RF signals to transfer information. Radio waves transfer data between an item with an RFID device attached and an RFID reader. The device may contain data about the item, such as what the item is, what time it traveled through a certain zone, and even additional information can be recorded includes characteristics such as pressure, temperature, moisture level, etc.

RFID devices, such as a tag or label, can be attached to anything. When its rewritable memory chip and wireless data communications capabilities are applied to every product shipped, an RFID tag allows a company to actively track changes in the status of each product at each step along its journey.

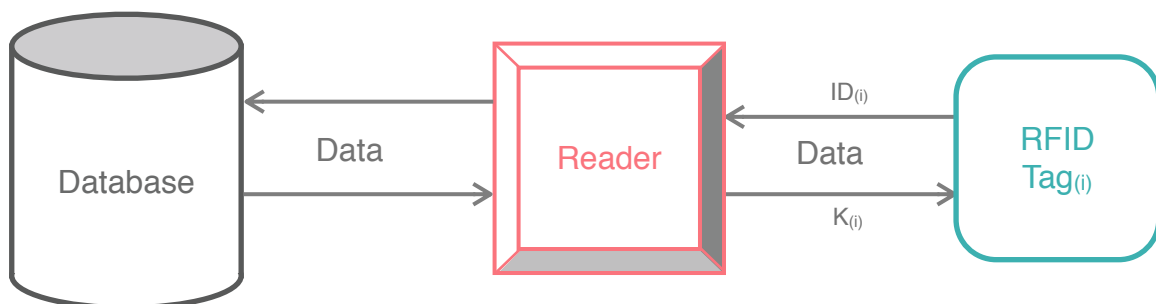


Figure 5.6. RFID communication between reader and database

An RFID “tag” consists of an application-specific integrated circuit (ASIC) and an antenna that can be mounted on various substrates (figure 5.7).

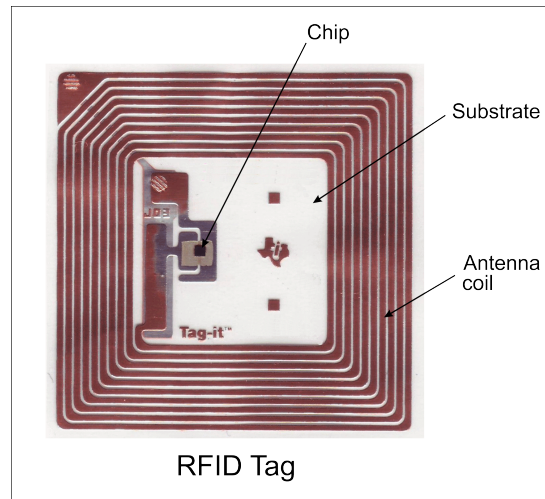


Figure 5.7. RFID Tag - main parts [25]

There are three basic types of RFID tags: active, semi-active and passive tags (figure 5.8).

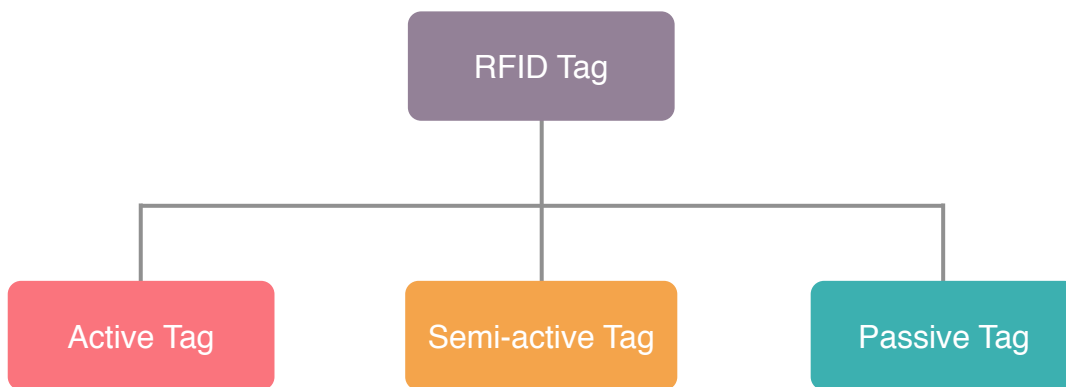


Figure 5.8. Classification of RFID tags [33]

Active tags carry their own power source (batteries) and can be read from a much greater distance since the tag itself is transmitting data, but they are larger and more expensive. Active tags have the capacity to store and process more data than passive tags and this is due to the own power supply, which is less sensitive to the strength of the reader's interrogation signal.

The second type of RFID tag that is based on power supply is the semi-active tag. The most significant difference between active and semi-active tag is that semi-active tag has the provision of an own power supply for minor signal processing tasks, but this power is not utilized for amplification of received and transmitted signals. Therefore a semi-active tag consumes much less power from the battery and has a longer life.



Passive tags are the most common used for automated data collection applications. When a passive tag is interrogated, the energy from the reader powers the tag, allowing it to be read and written to. The operation of passive tags has been compared to that of a mirror, which doesn't emit light, it simply reflects it back. The passive tag works the same way, reflecting back specific radio energy transmitted by the external reading device, with data applied on top of this energy. And since radio energy is being transmitted, the waves are generally able to pass through most non-metallic materials, such as paper, wallboard, many woods, and most plastics. The most important difference between RFID and other past technologies, is the possibility of identifying items without line of sight, simultaneous reading of several tags achieved by the use of anti-collision mechanisms and the ability to identify items.

#### ***5.4.5. Product Traceability System by Using RFID Technology in Marine Industry***

A new tendency in Classification Societies is switching from direct survey (inspection of a product without coming into the production phase in order to verify the production process) to Quality Assurance scheme, where the focus is not only on the product, but also on the production phase processes which are part of the manufacturing phase.

By implementing RFID technology the marine industry will be benefit for both, marine equipment and component manufacturers and classification societies. By using RFID tracking system, which is robust and accurate, the product quality would be increased and number of faulty components would be decreased. Therefore, such a system would contribute to significant cost savings for manufacturing companies.

For the Classification societies RFID marking system would contribute to confidence of manufacturing process, as well as significant by simplifying and time saving of the inspection process. By this system the traceability of each process is recorded in the tag and in a database also, which means that every production step is recorded and could be checked at any time by the Class Society to ensure that each part followed the same production process.

On the other hand, inspection processes for further stages will be simplified for Classification Societies and will require less time for that process. When the manufacturer producing under a Quality Assurance Scheme certificate<sup>2</sup>, the Class Society doesn't inspect every single

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<sup>2</sup> Special certificate that allow the manufacturer to inspect components without presence of Classes' surveyor (self-certification)

product any more, and when product is assembled and comes to next station or on-board, by RFID systems Class Society will be able to check that each component inside a product is the right one (e.g. it would be possible to check whether the crank shaft is properly certified in a diesel engine). At the most basic level, the party undertaking any action associated with the parts or equipment when reading the tag may enter whether the item has passed the inspection which is required and all another relevant information that is recorded in the tag. That information may also include date and time that an item left the manufacturer, was delivered and was installed on-board.

When a component contains several items which have to be inspected and each part is marked by RFID, we are able to check complete assembly by one reading of the component, as there is a masters RFID of final product (e.g. engine) collecting information from the others.

Some additional information could be recorded includes characteristics such as pressure, temperature, moisture level, etc. where it will be possible to build a history and maintenance record of that item throughout its lifetime.

A further advantage of the tagging system is that defective product reporting time could potentially be reduced. Once the information at a particular read time has transferred into the database, that information can be made immediately available. A tag based system hold the potential to report defective products on an almost 'live' basis.

The tendency today in the supply chain of any industry is to increase traceability of products, and some estimation for the future is that all products will have their IP addresses and it will be possible access to any parts and get information of it. In the figure 5.4. is shown the fixed RFID system that can read all tags in some place (e.g. on a vessel) and save the data to a database.

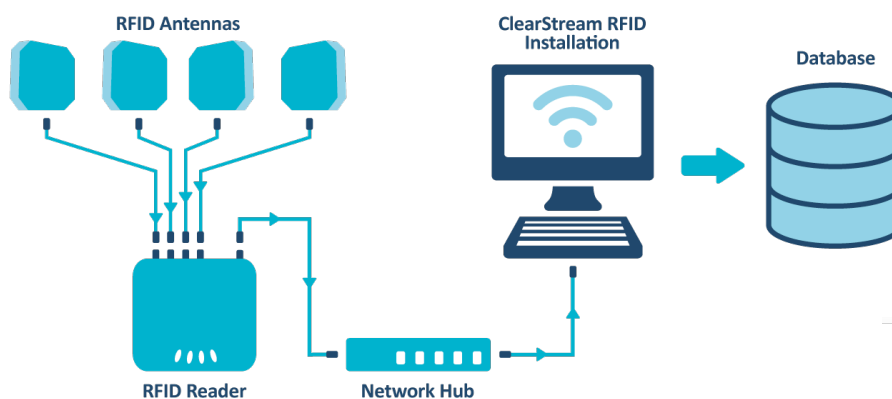


Figure 5.4. Fixed RFID system with connection to database [38]

Another very important advantage of RFID system is to prevent counterfeit products entering the market. The RFID tag will in fact replace Class' stamp, that could be easily falsified. The data inside the tag also can be falsified, but there are many methods that can prevent any falsification. When it is used a database which contain all information that are in the tags, then all the time data from the tags and database must be identical, if not then the tag is fake.

Further advantage of this system is when the ship transfers from one to another class. All data about each component of the ship are actually on the ship itself, and the new classification society has only to upload the data and store that in a new project file on the server (database). All the advantages and disadvantages of implementing the proposed RFID system are presented in following table (table 5.2).

Table 5.2. Advantages and disadvantages of implementing the proposed RFID system

<b>✓ Positive effects</b>	<b>✗ Negative effects</b>
Traceability of parts	Increased the process time due to the required extra steps
No faults forward quality system - Efficient supply-chain management	Necessity to re-adjust an existing or investment in a new machine
No incomplete products - ensure product has gone through required process steps	Cost of RFID tag
Visibility of parts assembled in final products or equipment that comes on-board	Cost of RFID readers and other equipments that needed
Inspection process is faster and simplified	Required training of inspectors to handle the RFID equipment
Could help prevent counterfeit products	A new application for the support of RFID system is required
Reporting defective products - can be used for product maintenance and service	New staff to support RFID systems needs to be employed

#### 5.4.6. Example of Using RFID for Traceability of Engine Crankshaft

In this example it is shown how an essential part of the engine - crankshaft (figure 5.9.) can be marked by an RFID tag. The developed solution consists of an RFID tag-enabled bolt that is to be screwed to the crankshaft to track it along the production line. Prior to starting the machining process, a blind tapped hole would be drilled either on the counterweight or on the flywheel of the crankshaft.

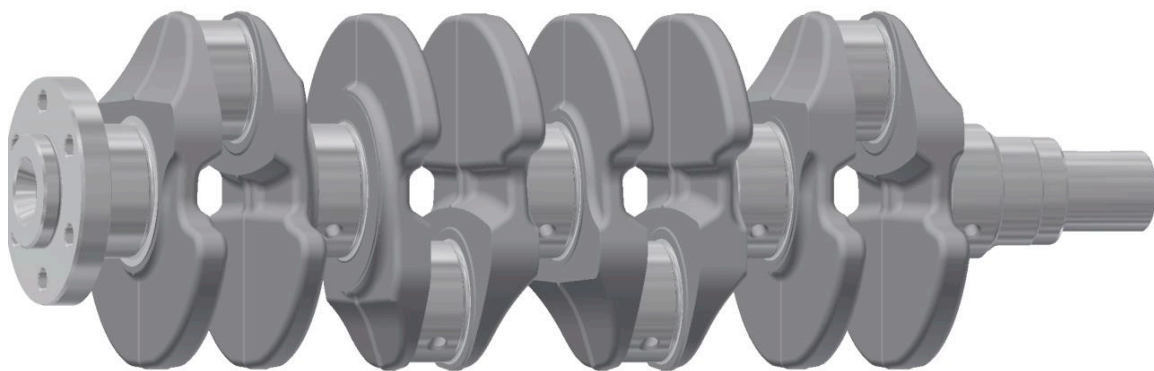


Figure 5.9. Engine Crankshaft[18]

The RFID bolt would be screwed in at the beginning of the production line and remains on the crankshaft until the end of the machining processes.

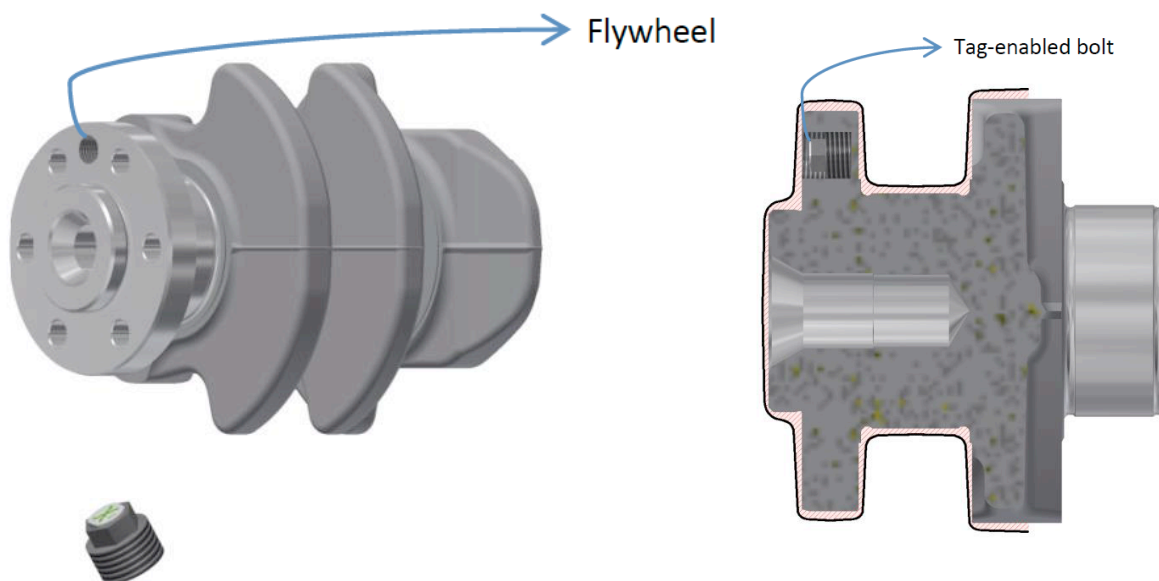


Figure 5.10. RFID concept solution of Flywheel end location[18]

The study has shown that the proposed technical solution can provide a robust and very reliable traceability system that would ensure no incomplete machining operations.

Therefore, it can be a very effective and efficient support for the new way of certification scheme based on quality assurance and processes control. However, the proposed system is not economically attractive in high volume manufacturing due to the current high costs of RFID tags, but for the case where the cycle time of the process is not such a critical aspect as in high volume, high speed engine production it appears very economical. In the marine industry, due to small volume manufacturing, the proposed system is economically accepted, due to the fact that safety is an important factor here and by this technology the reliability level of production phase will increase drastically. However, this is not only important for manufacturing phase and products quality assurance, it can be also implemented through the entire product life cycle, particularly for maintenance and servicing phase.

Another very important factor is that the classification audit of the part will be simplified, and even when the item is assembled in final system - engine it is still traceable. The tag will remain active over the life-spans of these tagged-parts, which is important for annually audit.

Lifespan of the parts and components in the marine industry, especially those essential, is very long (about 20 years), and the price is much higher, thus the introduction of this technology would not at the end increase the total cost too much.

The same technology that has already been implemented in the automotive and aviation industries has demonstrated positive results in terms of quality and safety. On the other hand forecasts indicate that the shipbuilding industry is moving in the direction of smart manufacturing and smart shipping, big data etc, where the implementation of such or similar technology is not in doubt.



## 6. CONCLUSION

The Marine supplies industry of today is following new principles of logistic schemes and smart manufacturing trends which can be characterized by:

- Flexible and short delivery times,
- Increasing utilization of smart manufacturing technologies (e.g. 3D printing),
- Globalization, unification of suppliers
- Use of complex data in all areas of supply chain services

To be able to follow these trends any kind of product certification method need to follow this trend and subsequently the business models need a review to meet the expectation of industry, i.e. from the traditional way to a new QA based, flexible approach to product assurance.

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In the thesis it was analyzed by taking the example of steering gear with comparing two different ways of product certification. The first way is traditional way of complying with prescriptive class rules under direct survey, where the second one is new and proposed way of introducing a certification process following the principles of a more QA and process based certification scheme. It is shown, that the traditional method of certification consist mainly of witnessing tests done by a surveyor and carried out at the manufacturer's location scoping many stages and production steps of the production. The manufacturer has to agree on the survey requirements, which means that the manufacturer is very dependent on a surveyor. The manufacturer is facing the risk of delivery delay if surveyors do not keep up the schedule of the manufacturers or other logistic problems. All this certification process is additional cost for manufacturer, not only for certificates but also for administrative work, because they need extra resource to deal with required logistic and e paper works.

A new option of certification process in marine supplies industry, based on QA appears as very good improvement of traditional (direct survey) process. Switching to QA scheme type of services as offered by several Classification Societies (CS), the manufacturer will have greater flexibility in the production process, especially if the manufacturer produces a complete product without subcontractors. However, if there are sub-contractors who have no a

QA based certification process, it reduces the effectiveness of this method, because they are obliged to follow the direct survey.

Another problem, which occurs in QA based methods, is annual inspections when the manufacturer has a QA scheme certificate from different classification societies. QA based certification involves frequently audits of the manufacturer's production processes, which might not relate to the number of manufactured products/parts. A large number of companies have one or more approvals with several approval bodies. Each of classification societies would perform annually audits, which are additional audits to the main suppliers audits and QMS audits adding up to a high number of annually audits and additional costs.

This is one reason that some manufacturers will continue to keep the traditional way of certification (direct survey).

Multitude certification is one of the main problems of the overall marine supply industry. They manufacturer cannot choose the certification body, i.e. the classification society; it is primarily ruled out by a contract between the end user and the equipment manufacturer. Having several international operating Classification societies is however necessary to keep the competitiveness in that sector and between them, which leads to improving of services and often reduction of prices. In recent times there is a notable trend to harmonization of standards and rules as in the case of EU mutual recognition regulation 391/2009.

In the thesis the author has proposed to separate products intended to be used in the marine industry based on their criticality. All non-critical parts could be certified following the EU RO MR model, which makes it non-necessary to apply for multiple certificates with different approval bodies.

The other option is instead of looking at the parts, we can consider a more process based certification model. At this moment some of the classification societies have rules related to support this approach. Therefore, it might be a step ahead to develop/adopt common procedures scoping all classification societies, on the basis of a similar principle as done under the current EU mutual recognition agreements, so annual inspection of manufacturing processes from one classification society would be acceptable to all others.

...

As we mentioned above, in the traditional certification process a surveyor is witnessing a product test to make sure the reading is correct and that the production process passed all the necessary steps and fulfills the specification requirements. For a QA Scheme based



certification process the manufacturer performs all tests, which means that the certification process is based on the confidence in the manufacturing capabilities. Traceability of parts in the production process and during the entire supply chain is another aspect increasing the safe use and quality control process, and one of the possibilities is definitely use of RFID (radio frequency identification). In the thesis has presented a possibility of implementing RFID tagging on the example of engine's crankshaft. By implementing RFID for traceability is further step to support QA scheme process, which will simplify and enhance the survey process. It is shown in study that by implementing RFID for marking essential parts of a ship, readability of the parts will drastically improve not only traceability of components but also improve other related processes like maintenance.

...

In the thesis are analyzed the certification processes of automotive and aviation industry. The certification process is a very important issue and each industry deal with that in a different way according to the relevance of the safety level criteria applied. Automotive and aviation supply industries have production in big series (mass production) and thus the certification process of products are mainly based on a pre-quality assurance type approach, which means they will test and approve prototype products before launching of serial production.

Automotive industry is highly consolidated and a handful of major corporations own nearly all of the world's major car brands, what is very convenient for the standards harmonization. Therefore, in the automotive industry has been developed a common standard TS 16949, which is accepted by all carmakers. In this standard are mostly integrated all needs from the different manufacturers in order to have required product quality assurance.

In the aviation industry suppliers have to meet very rigorous requirements in terms of quality assurance, and a company has to be on a high-tech level in order to meet these requirements. In most of the cases suppliers in aviation industry are from all over the world, and there is also a strong tendency for establishing harmonized standard. Therefore, a common standard (ASA9100) has been developed to provide guidance and procedures for product quality assurance for the aviation industry, which need to be accepted from all manufacturers and suppliers in that sector.

The Marine supplies industry comprises of a huge number of mainly small and medium sized companies that produce in relatively small series. Comparing to other industries (automotive

and aviation) their system of product certification is complicated and time-consuming. Mutual recognition and further harmonization of standards might offer one solution for the marine industry but more importantly the change from direct inspection to a more alternative way of process audit based approaches (QA schemes) would be a first step to close the gap between the practices applied by the aviation and automotive industry applying the principles of Product Lifecycle Management (PLM) in the same way.

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