# CHALLENGES OF PRODUCT MODULARIZATION METHODS IN SMES: LESSONS LEARNED FROM A MANUFACTURER OF RIGID INFLATABLE BOATS

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## ABSTRACT

Nowadays, Western rigid inflatable boat (RIB) manufacturers are facing increased competition from Asian and Middle East producers and the need to push the modularization of their product architecture. Many modularization techniques have been developed to support this effort, being the Modular Function Deployment a well-established multi-stage modularization technique with applications in several industries. Despite the reported literature, the challenges and learnings from the application of modularization techniques have focused on large organizations and complex product systems. In this paper, a case study is presented with the objective of analysing the MFD process implementation in the context of an SME manufacturer of RIB. A learning framework focused on the project and process perspectives is used to facilitate the systematic extraction of lessons from the experience of the MFD implementation. This paper contributes to the modularization techniques literature by observing a modularization method as a learning process and makes it evident the call for more investigation on the implementation process of modularization methods.

**Keywords**: MFD, Modular Design, Case study, Product architecture, Design learning

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## 1 INTRODUCTION

A Rigid Inflatable Boat (RIB) is a naval craft composed of a rigid hull, usually fabricated out of a wooden structure and glass fibre reinforced plastic, though other materials, such as steel or aluminium, are not uncommon, lined with high pressure, inflatable, air tubes along its sides. In general, RIB manufacturers produce the rigid section (the hull and deck) and the inflatable air tubes, and then join them together, while acquiring other equipment from outside sources, adapting the hull and/or air tubes as deemed necessary for each order.

In the last few years, the small-sized boat-making industry has seen a surge in demand for this kind of vessel. Growth in the leisure activities market, for which RIBs provide a fast, reliable method, while being relatively cheap, has supported the increase in demand. At the same time, its versatility, toughness and dependability allow it to satisfy both military and rescue operations requirements. These facts have forced the industry to expand its catalogue despite the fact that most of the current fabrication methods are still "artisan", one-of and made-to-order.

Modern, large-scale industries of complex products (for example, the automotive industry) encountered very similar issues in the past and have adopted several methods to address them, most of them being taken in the sense of adopting modularization techniques. One of these techniques, or methods, is the Modular Function Deployment, or MFD. It focuses on creating a path between the voice of the customer and the technical solutions that satisfy them, always keeping in mind opportunities to apply modularization. In this paper, the implementation of this method in a product modularization project of a manufacturer of RIB's is presented by, firstly, introducing the method itself, then detailing the context of the company and its usual production process. Finally, the difficulties encountered through the lens of a learning process framework and conclusions derived thereof will be presented.

## 2 LITERATURE REVIEW

Product modularity is a topic long discussed in the shipbuilding industry, particularly for the military, for its considerable potential for cost reduction and for the easiness of configuring warships according to operational needs (Ramsay, 2012). Other studies have also identified other operational contributions from product modularity, such as supply chain integration (Pero et al., 2015), flexibility and agility (Suh and Lee, 2018), as an instrument to address high competition and over-capacity (Lee et al., 2017), in improving communication and coordination in large scale projects (Tee et al., 2019) and extending the service time of ships since these can be configured to a large range of missions (Piñeros Bello and Segovia Forero, 2020). The modularity principle has also been used to demonstrate a framework used for life cycle assessment for the selection of marine propulsion systems (Jeong et al., 2018).

The RIB is a market segment in the shipbuilding industry. Given its simpler product architecture, RIB manufacturers experienced the push for product modularization later compared to other (more complex) shipbuilding market segments. In fact, by the beginning of the previous decade, modularization was not very common in ship design and building except for a few European design companies (Lehtinen et al., 2012). Modularity was hampered by significant challenges relating to the investment required in production machinery and in training engineers and designers, and the need to coordinate a set of suppliers that deliver modular equipment and components (Daidola, 2021; Pero et al., 2015). The business environment in which these companies operate tended not to favour modularity since overcapacity in shipbuilding encouraged ship buyers to own the definition of technical solutions, which then led to a situation where ships are designed and fabricated according to a single customer's requirements, as opposed to a logic where standard platforms are offered and modules are integrated for specific customers' segments. Faced with fierce competition from Asian and Middle East producers in recent years, Western RIB manufacturers have now to deal with the challenge of rationalizing their design and manufacturing methods. Companies started to look at the best practices from other industrial segments and sectors, and modularity has been gaining attention for its promise of increasing product variety in an operationally efficient manner. Studies have shown promising results in the application of product modularization methods in the shipbuilding industry (Bradshaw et al., 2012; Smith et al., 2001).Yan et al. (2007) argued that the implementation of formal modularization methods benefits organizations in terms of quality, cost and performance, rather than relying on designers' tendencies.

Pressured by market forces that, small and medium enterprises (SMEs) shipbuilders are now faced with the need to rationalize their manufacturing operations without compromising product variety, there is a renewed interest in the applicability of such techniques in naval-oriented SMEs. Despite this, literature about product modularization methods has traditionally focused on large complex naval systems, with studying design aspects of the project rather than on the managerial implications of the method's implementation, a particular concern, especially for SMEs that are traditionally not used to these design management methods. In fact, embedding novel design management techniques in SMEs has long been characterized as a troublesome process in reported literature (Pearce et al., 2018; Schlierer et al., 2012; Ward et al., 2009). In order to fill in this gap in the literature, this paper reports the application of a known method to support the modularization of product architectures – Modular Function Deployment – in a Portuguese SME that manufactures RIB for different maritime segments. Supported by a structured learning framework, the objective of this study is to draw managerial lessons from the implementation of a modularisation method a in mid-sized organization.

# 3 RESEARCH METHOD

This study employed a single in-depth case study, where the research team were not merely observers of the process, but often participated in the discussions, assuming the role of facilitators. However, the case study employed differs from action research, since the researchers did not intervene in the decisions made by the design team (Saunders et al., 2009), which means that the researchers are limited to studying, analysing and describing situations.

The implementation process of a modularisation method within the context of an SME was the object of study by the research team, with the main objective of drawing lessons that, in their turn, contribute to nurturing the absorption of new-to-the-company design management techniques.

## 3.1 Case study

The company involved is called "Vanguard Marine", referred as VM for the rest of this paper, and is a mid-sized RIB manufacturer, located in the northern region of Portugal. They produce several models of RIB's, with varying sizes, shapes, types of motorizations and purpose. Their products are used by several sectors including Defence Agencies, Rescue Organizations, the Naval Industry and SOLAS-compliant (International Convention for the Safety of Life at Sea) Rescue Boats. Almost every vessel manufactured is personalized to the customer's requirements, with several "standard" options offered in catalogue form.

In a response to the increasing challenges faced by foreign competitors (as mentioned in sections 1 and 2) VM engaged in a product modularization project of a 12 meters long vessel, targeted towards 4 market segments: Search and Rescue, Ambulance, Tourism and Marine Observation. The reason for selecting these markets is related to the need identified by the company's top management to enter new markets (Ambulance and Tourism) while maintaining the requirements and knowledge acquired on the requirements from the market segments where the company is already present (Search and Rescue and Marine Observation). In this way, the modularization project would enable the expansion of the range of products offered to the markets, benefiting from the experience already acquired with the others. At an operational level, there was an increasing need to create standardized interfaces that would facilitate the assembly of equipment and accessories on the deck of vessels, so this modularisation project was configured as an opportunity to move forward in this direction. Finally, at the level of choice of modularization support method, there was a basic requirement related to the need to integrate technical and market perspectives, as will be explained later on.

The goal of the project was to reach a set of product concepts that would modularize a vessel in such a way that it could satisfy all these market segments with easily reconfigurable options. This should facilitate production and solve some of the major manufacturing management problems currently afflicting the company.

Despite offering "standard" configurations for several key areas of the RIB market, the vast majority of VM's purchases include some form or other of individuality. For the most part, this individuality comes in the form of specific communications and/or navigation equipment, specific seats or safety gear, not to mention custom livery. Their manufacturing environment is characterized as a "back-and-forth" between project managers and assembly floor workers as obstacles not foreseen during the planning stage of the project are encountered, which negatively affects operational efficiency.

In their search for an applicable modularisation method, early on the company made some considerations in terms of the requirements and desirable features that the method should fulfil. The company management considered that the involvement of the engineering and marketing teams would be critical to assess the design of the interfaces (i.e., fixation principles, contact surfaces, attachments, etc.) due to the product strategy orientation of the company in offering a shared platform in which different configurations could be achieved by interchanging modules for different markets.

Another relevant consideration made is related to the inclusion of strategic considerations in the product modularisation method. The identification of which parts, components and/or systems could be modularized was not the only objective of the company, but rather addressing strategic intents or drivers in the identification process. In other words, driving forces behind modularization should be considered to indicate the way parts are combined into modules (for example carry-over, recyclability, etc.).

Repeatability was not a concern since the focus was on a single product. In addition to this, since this was the first time a modularisation method was incorporated in the product development process of the company, the method should be adaptable to changes during implementation, and should also facilitate the handover from conceptual to detailed design phase.

In order to support selection on solid scientific knowledge, the research team from INEGI in conjunction with the company dedicated time reviewing the literature which presented analytical comparison between different modularisation methods (Borjesson, 2010; Katja Holtta and Mikko Salonen, 2003; Pirrung, 2004). A total of nine different modularisation methods were assessed in these studies following multiple criteria. Overall, the Modular Function Deployment (MFD) method is pointed as the most comprehensive method and most applicable to the early stages of product development (Pirrung, 2004), such was the case under study in the company. The method is also assessed as being flexible to changes, capable of dealing with multiple data types and sources (such from the engineering and marketing teams), as facilitator of design handover and supporter of interfaces generation (Borjesson, 2010). Finally, the MFD was designed to modularize a single product, thus being the least repeatable of the methods, and most suitable for strategy-based modularisation (Katja Holtta and Mikko Salonen, 2003). Therefore, the MFD was the modularisation method selected for implementation.

Although the reviewed papers do not cover the full spectrum of modularisation methods (for example Design for Variety of DFV), the decision was based on requirements and criteria set by the company for which the MFD, out of the considered modularisation methods, was identified as the most suitable.

## 3.2 Modular Function Deployment

Modular Function Deployment, or MFD, is a process developed by Gunnar Erixon and first shown in Erixon (1998). A standard MFD implementation process has 5 steps, as seen in Figure 1.

The first step involves the characterization of the target Market Segments. This characterization aims to homogenise the team's view of the subject and ensure that all design requirements are related to customer needs. Followed that, a list of customer requirements ("Customer Values" or CV) and physical characteristics ("Product Properties" or PP) extracted from said Customer Values is created. Each Customer value is then weighted according to its importance to the Market Segment and its influence on the Product Properties using the scale 0, 1, 3 or 9. This lopsided scale is used to contradict bias and give emphasis to the more important relations. This first step is also where the focus of the implementation is decided by considering any new ideas, current setup of the product and changes that have already been decided upon.

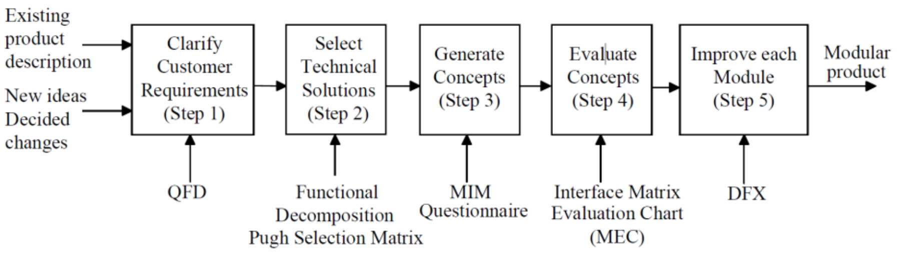


*Figure 1. Modular Function Deployment (MFD) process steps. Source: Erixon (1998).*



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This information, as well as all information collected throughout the process, is organized in a QFD matrix, with each successive matrix relating to the previous one with the aim of creating a visual path between the final Modular Concepts and the initial Customer Values.
The second step starts with a Functional Decomposition of the product. The functional decomposition aims to deconstruct both the product features and the experts' unconscious bias towards assumed facts. For each identified function, a Technical Solution is selected. Erixon advises the use of a Pugh Selection Matrix to compare different Technological Solutions, although this is not the only tool available and its use is not mandatory. The resulting list of Technical Solutions forms another entry into the relationship matrix and each solution is weighed, using the same system as in the Costumer Values - Product Properties weighing, against the Product Properties.
The third step is the introduction of the Module Indication Matrix. Here, a set of previously discussed and agreed incentives for modularization ("Module Drivers") are weighed against each Technical Solution. Possible groups of Technical Solutions are identified, by observing groups of heavy weights in the same Module Driver, and early module concepts are suggested. A standard questionnaire is also provided by Erixon. This questionnaire is, again, not mandatory and even the Module Drivers suggested by Erixon can be adapted to suit the projects scope.
Finally, in the fourth and fifth steps, the interfaces for the Module Concepts are described and evaluated in regard to their complexity and their compatibility with defined assembly methods. Module Concepts that prove themselves to be satisfactory are then characterized and a profile file is created. This file needs to have enough information to allow the next step of the design to continue, outside the method, as well as to facilitate future iterations of MFD implementation. The method does not need to finish with a complete product, only a concept and a set of indication that will guide the next design stage.

### 3.3 Learning frameworks

During the planning of this study there was a need for a framework to support the analysis of the results of the implementation of the method in the organization, which could in turn offer a structured and analytical perspective over the concepts supported by scientific literature.
Since the beginning of implementation, the company focused on project management, particularly on one specific process - lessons learned. This process aims to capture the experiences (good and bad) and incorporate them in organization processes for improving future relatable projects. Considering that this was the first time that a product modularization method was implemented in the company, the objective of the study was to identify lessons that would allow a more effective implementation in future projects. For this reason, the scope of this study was centred on the project management knowledge field, particularly on lessons learned frameworks. However, it is recognized that there are other frameworks with potential application in the analysis of this article's results, especially related to design theory (Reich and Subrahmanian, 2022a, 2022b).
In order to analyse the lessons learned through the MFD implementation process, the research team adopted the framework developed by McClory et al. (2017). In their work, the authors propose a triple-loop project learning framework which is an evolution from the single and double-loop project learning frameworks, in a response to an identified need of organizations for improving the way lessons learned are captured in projects. Project learning frameworks consider knowledge management and organizational learning as core processes in the whole cycle of the project management activity and embed them in the organization in "…learning management modules" (McClory et al., 2017, pp. 1323). The single loop characterizes a learning process where outcomes are measured and evaluated to support decision-making that brings the project back on track, culminating in the closure of a project. The second loop goes further to include not only the evaluation of project parameters but also the assessment of underlying processes to ensure that their implementation meets higher level goals of both the project and organization. This occurs concurrently with single-loop learning. Finally, the third loop (the authors' proposition) is a meta-process, in the sense that characterizes the learning organization or, in other words, an organization that has the capability to learn about learning. This involves the organization's cultural values and goals, enabling the conversion of tacit knowledge into explicit knowledge through the expression and sharing of experiences, meaning that, at this level, the organization has achieved a higher level of maturity in their learning processes.
In this paper, the research team used the middle layer of this framework, which incorporates both the project and process perspectives. For both perspectives, the six phases of the framework are: 1) Act, 2)


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Measure, 3) Evaluate, 4) Decide, 5) React and 6) Learn. The lessons gathered throughout the implementation of the modularisation project are analysed through these six phases.
The research team was not involved in a study about the organization, since the unit of analysis was the product modularization project implemented in VM ("the project") resorting to the modularisation method ("the process"), and the implications of the implementation process for the organization to achieve its goals in terms of the modularization of its product offer. The lessons learned are discussed and identified in section 5 through the lenses of the double-loop project learning framework.

## 4 IMPLEMENTATION OF THE METHOD TO THE USE CASE

The MFD method was implemented over the course of a year. Workshop meetings occurred between the research team of INEGI and the design team of VM once, sometimes twice a month with clear goals set for each meeting. The team in charge of studying the implementation of the method was composed by 2 research engineers from INEGI, both familiar with the MFD method, and 4 elements from VM. From VM, two of their elements had deep knowledge of the product and its production process while the other two were more involved in the logistics and operations management of the company.

### 4.1 Step 1

In order to reach a good set of CVs, at first, VM shared with INEGI's research team several previous contracts coming from the different market segments selected for the use case. More specifically, the sections of the contracts where the requirements of the naval craft were specified. This allowed for a set of Costumer Values to be reached. These Values were then refined by the expert knowledge of VM's team members. With these, the Customer Values were translated into Product Properties. At the end of the step, there were 21 CV, differently weighed relating to the 4 different Market Segments, and 48 Product Properties, also weighed against each Customer Values.

### 4.2 Step 2

For the functional decomposition and the selection method, it was decided to enact a top-down approach, mostly so that there could be a higher level of "questioning" of commonly assumed facts and used solutions and that the level of bias from the team members could be minimized. The resulting tree diagram, showing the Functional Decomposition, is seen in Figure 2.
It proved difficult, without any measurable way or demarcating line indicating how far to go with the decomposition, to know when to stop. Ultimately, it was decided to stop the decomposition at the third level of sub-function since, below that, the technical solutions that would be chosen were outside the control of VM and into the realm of the component suppliers and the component construction.
With the accepted list of functions, the work proceeded by questioning which TSs did each function. Most of the agreed technical solutions were already part of existing technologies and used solutions. This due to the fact that the vast majority of the solutions were part of equipment not produced in-house, instead being ordered from other equipment manufacturers and then assembled as requested by the customer.

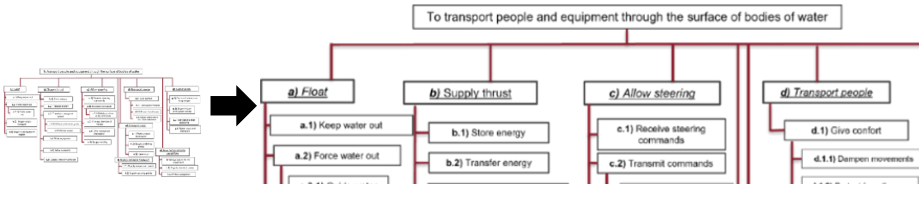


*Figure 2. The tree diagram reached at the end of the functional decomposition process. (Detailed View)*

### 4.3 Step 3

At this point of the process, a decision had to be made due to the limited design freedom at the component level, which in turn restricted the capability of the company to evaluate concepts, leaving the product architecture design changes as the only possible way to move forward. Using a, for example, singular hull and deck combination, different configurations of vessels could be made in order to satisfy each of the Market Segments without new technological systems being needed. The


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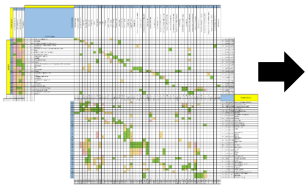
issue that presented itself was the fact that, once a configuration was selected and applied, it was nearly impossible to change it. The overall Assemble-To-Order (ATO) nature of the product in combination with the fact that most accessories required to finish it were outsourced and individually specified in each contract, made senseless the attempt to group them together. Nonetheless, the matrixes were rearranged, and the result was the matrix shown in Figure 3.



| Customer Values | Fuel Deposit Size | Fuel consumption | "V" Hull Geometry | Float Line | Deck Geometry | Deck Layout | Floatability | Width | Hull Geometry | Height | Lenght | Fuel Type | Engine Efficiency | Total Weight | Engine Location | Propulsion type | Engine Type | Total Horsepower | Console Layout |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Have Good Autonomy | 9 | 3 | | | | | | | | | | | | 3 | | | | | |
| Be Stable | | | 9 | 3 | | | | | | | | | | | | | 9 | | |
| Be able to transport many passengers | | | | | 3 | | 9 | | | | | | | | | | 9 | | |
| Be capable of transporting debilitated passengers | | | | | | 3 | | | | | | | | | | | | | |
| Be able to be carried and deployed by other naval craft | | | | | | | | | | 9 | | | | | | | | | |
| Easily transportable through land | | | | | | | | 9 | | 9 | 1 | | | 3 | | | | | |

*Figure 3. Section of the rearranged matrix*

As such, the only concept suited to the company's production methods was the anchoring or interface panels for modular assemblies on the deck. For this reason, the implementation did not continue to steps 4 and 5. In step 3, the Modular Indication Matrix (MIM) was not implemented since only one concept was generated. With this, an analysis was made to see what TSs arranged themselves into groups of strong and medium relations. This would indicate that these groups of solutions influence a certain group of PPs and, by proxy, a certain group of CVs.

From this process, it was possible to recognize groups of technologies that seemed to answer similar concerns and influence similar groups of PPs. VM then decided to develop a set of intermediate fixing plates. These would all have the same anchoring to the main deck and include different patterns of pre-installed inserts. This will allow to quickly swap parts, as the main impeding factor to this was the difficulty of creating new mounting points in the fibreglass structure of the craft (and closing the old ones). These plates would be created in groups, attending to the groups found by analysing the matrix and the physical location of the technical solutions. They could also be made out of a material other than fibreglass in order to facilitate their creation. This strategy will be an evolution from the company's previous platform strategy, adding modularization to what would otherwise be a fixed configuration. Furthermore, in addition to an analysis of the MFD results, there is also a need to analyse the industry's accessory suppliers. This analysis could bring to light further modularization opportunities for VM as, in addition to creating anchoring plates according to position and function, anchoring plates could be planned according to clusters of similarly anchored accessories form different suppliers.

## 5 IMPLEMENTATION OF THE METHOD TO THE USE CASE

The MFD method was implemented in VM during a series of workshops. During these, the research team gathered notes that reflected the main lessons learned. These lessons notes were then presented in the beginning of the following session as keynote for the company's engineering and marketing teams to discuss over and address the challenges ahead. The resulting list of lessons learned during the MFD implementation were then organized into the learning framework presented in section 3.3.

The product modularization project faced two major issues. Given the limited design freedom of a company that assumes an ATO manufacturing strategy, the deck layout proved to be the most prominent design feature for modularization. The reason behind this is intimately related to the four market segments, which dictated that the positioning of equipment on the deck played a significant role in the appeal to one. The engine power and navigation equipment played a minor role in the modularization project since the objective was to create modules of the vessel's architecture and not its components. The decision was to create new interfaces and fixation panels to assemble the equipment on the deck, enabling the quick reconfiguration and layout changes according to each market requirements, in a late customization fashion. An earlier recognition of the prominence and centrality of the deck layout in alignment with a clear modularization goal could have facilitated the project insofar as the focus could have been brought forward and more time and effort devoted to the design of the interface panels, accelerating some of the MFD steps. In fact, Sonego et al. (2016) argued that, in low novelty projects, the first two steps of MFD can be skipped since customers' requirements are already known and technical solutions have been long established.



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Also, the project suffered from few modularization opportunities given the reduced design freedom of VM. Long-established TSs meant that supplied technologies have already incorporated a considerable degree of standardization, leaving less autonomy for modular parts and components, whereas the only opportunities lied in assembly interfaces. The recommended course of action in these cases is the early involvement of suppliers in the product modularization project.

Perhaps the greatest challenge on the process level, meaning the MFD process, was the actual understanding of the method's concepts and artefacts. It was the first contact and practical implementation with a modularization method by the design team of VM. The language and questions used proved to be very important, particularly since the product expert's answers tended to focus on definitive technological solutions. This was especially true during the first stages of the implementation, as most CVs were directed to specific solutions (e.g.: "The Customer wants boarding stairs." as opposed to "The Customer wants to easily board and exit the vessel from/to a dock."). It was found that directing the product experts to a function, and performing a quasi-functional decomposition, answered satisfactorily in order to advance the implementation. When extracting PPs, it was found that having well-defined CVs was extremely important.

Another concern was the uncertainty about the usefulness of the information. The method directives are, by its very nature, flexible. Although in one hand this can be one of the main advantages of the method, on the other this led to difficulties in deciding what should constitute a PP or how far to go in the functional decomposition. The concept of PP was hard to separate from specific TSs. Care had to be taken with the questions posed to extract the PPs from the CVs. Asking such questions as "What satisfies CV 5?" usually led to the PP that came from it being tied to very concrete solutions, most of the time commonly used ones. An additional workshop meeting had to be held to restructure the process to ensure that a shared and homogeneous platform of understanding was achieved. Another issue that the research team observed was that, although following the instructions of the method in step 2, four PPs had not been matched to any TS. Upon a review and given their characteristics, it seemed that the unmatched PPs should have found corresponding technical solutions in the list. It is possible that the PPs were ill-defined and should be placed as TSs instead. The process moved on, but one can't ignore potential inaccuracies in the evaluation of TSs.

Finally, and perhaps the most difficult concept to correctly put forth was functional decomposition. The functions reached tended towards specific pieces of equipment. This slowed down the process flow and continuity. To mitigate this phenomenon, the two parts of the team decided to create separate functional decompositions. Then, by comparing both decompositions, it was possible to reach a tree diagram deemed acceptable to continue with the method.

The research team was in a privileged position to draw lessons and considerations for future implementations. These were then organized and summarized through the project learning framework proposed by McCloery et al. (2017) at both the project and process levels.

At the project level two issues were identified, referred to as "Deck Layout" and "Modular Assemblies". As to the "Deck Layout", this was identified as the most important product property for modularizations, in the "Act" framework step, and, as such, modular solutions should focus on the layout configuration, (the "Measure" step). This had a significant impact on the project, narrowing the choices available, and leading the team to focus on the anchoring plates solution, ("Evaluate" and "Decide" steps). The "Reaction" was the decision to develop 7 new prototypes of these plates. As a "Lesson", this shows that the centrality of certain product properties should be recognized early in the project. Regarding the "Modular Assemblies", the main issue found was that the solutions available from suppliers had closed designs with little flexibility, limiting opportunities for modularization, ("Action" and "Measure steps). The "Evaluation" was that of a significant impact on the project and, much like the previous issue, the "Decision" was for the team to focus on an intermediate anchoring plate between technological solutions and the deck. Possible solutions to this issue, ("Reaction"), are a tighter relationship with suppliers, increasing their involvement in designing new solutions. The "Lesson" is that ATO SMEs have low bargaining power, limiting their options.

At the Process level, three issues were identified, namely "Product Property", "MFD Concepts" and "Functional Decomposition".

The "Product Property" issue relates to the fact that, at the end of the process, three identified PPs had no Technical Solutions, (the "Act" step), contributing to potential inaccuracies in their evaluation ("Measure"). This could be due to inexperience at developing functional decompositions or due to faults with the product design, causing a medium to high impact on the project - the "Evaluation".



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Since, in conversation with the product specialists, the PPs did not seem to affect the processes' conclusions, no action was taken, (the "Decision" and "Reaction" steps). The "Lesson" was the acknowledgement of the need to do multiple, iterative passes through each step of the process. Throughout the project, the design team of Vanguard Marine faced difficulties in understanding the concepts of the MFD process. In addition to that, it was hard to assess the quality of the information being extracted from the meetings - the "Act". This fact may lead to a significant impact in the quality of the final product, ("Measure" and "Evaluation" steps), leading to the search for novel methods of teaching the different concepts and tools of the process to elements not familiar with it and extending the teaching period. This was the "Decision", leading to the "Reaction" of adding workshop sessions aimed at "teaching" the method. The "Lesson" was that, to mitigate this issue, knowledge assessment interviews could be conducted before the process' first steps. Finally, the "Functional Decomposition" tool was also hard to implement. Difficulties were encountered in understanding at what level this decomposition should stop and the detail required for the project - the "Act". This led to a lengthy, frustrating process that could influence the quality of information extracted and potentially highly impact the project (the "Measure" and "Evaluation" steps). The functional decomposition was stopped at the component level (the "Decision"), while the "Reaction was to make two separate decompositions and then joining them. To mitigate this issue, a discussion on the scope and main focus of the project should be had, delineating clear limitations (the "Lesson").

## 6 CONCLUSIONS

The absence of any previous attempt at product modularization at VM was a significant challenge for implementing MFD. This issue was identified early and the research team observed this as an opportunity to learn from this implementation in the context of SMEs.

The main contribution envisioned for this paper lies in observing the implementation of a modularization method as a learning process. By doing this and supported by a structured framework, the research team was able to capture lessons about the MFD implementation by participating in the Workshop sessions as observers. It is expected that these lessons will contribute to refinements of the method in light of organizational context (culture, values, experience, etc.) and other externalities (supply chain, competition, etc.). A useful lesson drawn from the case study was that special care should be given to the first sessions of the implementation. The MFD method is a powerful tool to question assumptions and bring forth tacit knowledge about the product but a rushed start with poor-quality data and no clear objective other than implementing the method can lead to sub-optimal results.

As regarding to RIB crafts and their modularization, the main conclusion reached was that focus should be given not to changing current technologies or joining them in groups. Instead, given the already modular nature of the product, the best path going forward was to create a set of anchoring mechanisms that, having a common way of being installed, could accommodate different sets of equipment. The main conclusion at the design level is that, organizations with an ATO strategy and with a degree of external dependence, should put their efforts on the standardization of assembly interfaces in collaboration with their suppliers. The groupings of technologies reached through the analysis of the MFD matrixes should be a good guideline for this development, in addition to a technical analysis of the of standard equipment available in the market. One limiting factor about this process was its focus on product architecture, as opposed to modularization at the component level. This could lead to wider conclusions, namely in the involvement of the supply chain in the design decisions and their implications for the management of the modularization project supported by a structured process. Future work should focus on extending the use of modularization methods in SMEs from other industrial sectors. The struggle many Western SMEs face nowadays calls for more investigation on modularization methods.

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