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Optimization design of remotely operated vehicle (ROV) for Madura Strait Area

I N Afifudin[1], A Nasirudin[1*], W D Aryawan[1], H A Kurniawati[1], Hasanudin[1], D Utama[1] and E I Putra[1]

[1] Department of Naval Architecture, Sepuluh Nopember Institute Of Technology, Indonesia

*anasirudin@na.its.ac.id

Nowadays, the development of unmanned vehicles is significantly increased. Since the remotely operated vehicle (ROV) has more advantages than Diver. Then, ROV has an important role in underwater inspection and research in various sectors, such as offshore infrastructure development. ROV will give some critical information to the operator about an underwater inspection like bathymetry, pipeline inspection, and the other crucial subsea structure that the divers can't reach. The optimization design has been carried out to determine ROV operational requirements in Madura Strait by Total-Based Method. ROV will be divided into 3 leading function groups, they are Features, Survive and Operate. Every group will be divided into Function Breakdown Structure (FBS). FBS will be divided again into Work Breakdown Structure (WBS). The optimum design will be determined by linking every breakdown function. The results are the ROV has 2MP 1080P resolution for camera, 2000 lumens for lighting, 50 m detection area for sonar and echosounder, 100 N grip force for Gripper, equipped with stainless steel frame, 2 hours long for operational duration, 5kg.f for thruster, operated with cable 300 m long and equipped with 6-unit thruster.

1. Introduction

As an archipelagic country that has more than 15,000 islands and abundant natural resources of offshore oil and gas, the infrastructure and underwater installations in Indonesia are huge and varied. Underwater structures in Indonesia not only consist of supporting infrastructure for the oil and gas industry such as subsea pipelines, subsea risers, Pipe Line End Manifolds (PLEM) but also consist of submarine cable installations for inter-island connectivity, namely as a means of communications (underwater internet fiber optic cable network) and underwater power cables. Monitoring and inspection of underwater structures must be carried out every certain period to identify potential damage/disruptions to ensure the technical, security, and safety functions of underwater infrastructure installations.

The rise of offshore mining activities and the construction of submarine pipelines and cables, has resulted in more and more underwater observation activities. This has an impact on the number of companies that have started to provide underwater survey services to support the development of underwater infrastructure. Currently, offshore survey activities are generally still carried out directly by divers.

Meanwhile, the need for surveys, inspections, and underwater operations for industry and research in Indonesia is urgently needed considering that Indonesia has a water area of more than three million

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km^2 with abundant potential for underwater natural resources and the existence of underwater installations and infrastructure that must be maintained. The technology for monitoring and inspection of underwater installations is needed for the oil and gas industry to inspect the condition of underwater pipes and underwater structures, while for the telecommunications and electricity industries, the technology is needed for monitoring and inspection of submarine cables.

Underwater monitoring technology in general can be used by underwater robots commonly called Underwater Remotely Operated Vehicles (ROV). Underwater ROVs are usually purchased and imported either in whole or component form. imports which are then assembled domestically. Underwater vehicle technology is very complex both in terms of underwater hydrodynamics, underwater motion, underwater maneuvering, control systems, navigation, and data retrieval and processing processes. Underwater monitoring and inspection require data retrieval tools such as cameras, sonar, and the like, which must then be properly transmitted to the surface. The depth factor is also a challenge related to hydrostatic pressure, underwater currents, and lack of lighting.

The industry activities of the oil and gas industry in Indonesia are also increasingly widespread as evidenced by the many constructions of underwater pipelines. One example is the construction of an underwater gas pipeline in the Meliwis gas field located in the Madura area of East Java. Besides Meliwis, two other gas fields are actively operating, namely the Opportunity gas field and the Maleo gas field. The gas pipeline being built stretches for 142 kilometers from the Madura Strait to Porong and Surabaya. The study and development of autonomous underwater vehicle technology absolutely must be developed independently by Indonesia to support underwater operations.

Based on the background above, this research was conducted to design an unmanned underwater vehicle/equipment Remotely Operated Vehicle (ROV) to assist the underwater inspection process in Indonesia. Remotely Operated Vehicle (ROV) can be a solution for underwater inspection activities in a safe way and a much better cruising depth when compared to being done manually by divers, especially for the Madura Strait area.

2. Total Design Method

The methodology of Total Design provides a design framework for a structured design process model for the application of design methodology in design practice by industrial practitioners. The unique contribution is called the Concept Selection Process to iteratively select the best concept from a number of candidates based on some criteria using a Concept Selection Matrix (or Pugh Matrix) [1]. The generation of all viable alternative design concepts improves the range of choices for the design and produces better outcomes for the project [3].

The activity of total ship design is conducted from two important analyses, cost and effectiveness analysis [4]. Total ship design is representing the sum of all ROV sub-systems and the ROV component parts then combined into the global function system of ROV. Then, the global function (GF) system of ROV is clustered into 3 Main Function (MF) categories that represent an ROV, there are Feature, Survive and Operate. Features describe the special ability of ROV. Survive describes the ability of an ROV to maintain the operation as long as possible. Operate describe the ability to achieve the mission.

2.1 *Step of Design*

The first step of the total design method is the global function will be divided into Function Breakdown Structures (FBS) which represent the derivative of the global function. Then the second step is FBS will be divided into Work breakdown structures (WBS) which represent the component of ROV to perform the FBS. The third step is WBS will be divided into Cost Breakdown Structures (CBS). CBS represents the price of ROV components. Certainly, every ROV component part has various prices. The fourth step is CBS will be divided into Specification Breakdown Structures (SBS). SBS describe the characteristic of ROV components. The fifth step is SBS will be divided into Dimension Breakdown Structure (DBS). DBS describes the value of component specification. The last step is giving the weight value in every breakdown function of ROV. The step of the total design method is shown in figure 1 below.

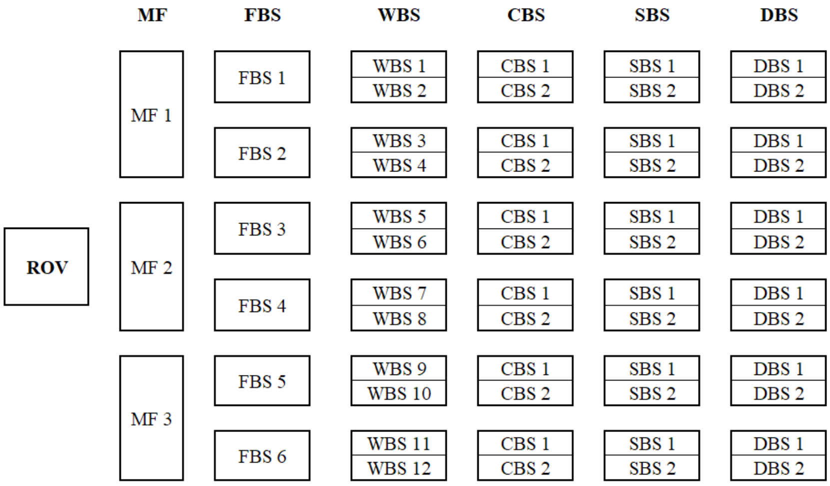

Figure 1 Total Design Method.

The combination design is obtained by linking in each Main Function to Dimension Breakdown Structure by means of the ROV Function. Then the optimum design of ROV is determined by the design that has the highest weight value for every combination ROV design.

2.2 *Weight Value*

The most important step to determine the optimum design is the weighting step. The determination of weight value is regarding the function of ROV when to be operated in Madura Sea Strait Area. The highest value meets if the function compatible with the operational condition in the Madura Sea Strait area. Regarding the geographical condition, Madura Sea Strait Area is located at 6,25° – 8,35° south latitude and 111,95° – 114,95° east longitude.

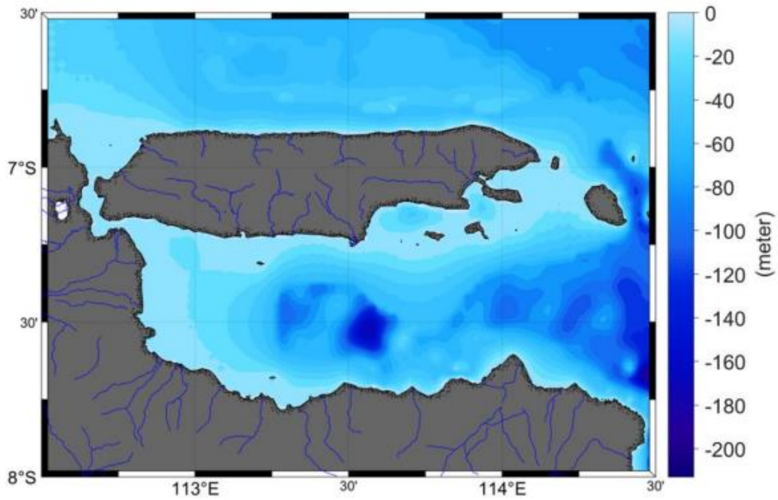

Figure 2 Madura Sea Strait Area.

The bathymetry of the Madura Sea Strait area is given by the General Bathymetric Chart of the Oceans (GEBCO) [5] is shown in figure 2 above. Figure 2 describes the water depth condition of the Madura Sea Strait Area has an average water depth between 20 m – 100 m and the deepest water is 200 m. Regarding to this condition, ROV will be designed to fulfill the water depth in the range of 200-300 m.

3. Design Limitation

As a full system, ROV consists of several sub-systems and components. This sub-system and component will be integrated with each other to develop the ROV function. Due to the complexity of

the ROV system, the limitation design will be performed. The limitation design will give the iteration process design in every breakdown process shortened.
ROV usually has various functions depending on how the owner's requirements and how much the owner's budget is, then the limitation focused on Function Breakdown Structure (FBS) and Cost Breakdown Structure (CBS). FBS will be determined in 9 sub-functions regarding the ROV operational condition in Madura Sea Strait area while CBS will be determined between 1 into 3 component prices as comparison data, the combination of design will be performed. The price of components collected from the market. The cheapest component will have the highest weight value and the most expensive component will have the lowest weight value. This method will be relevant since the owner will provide the cost to buy/design the ROV as cheaply as possible.
The full design framework shown in figure 3 below.

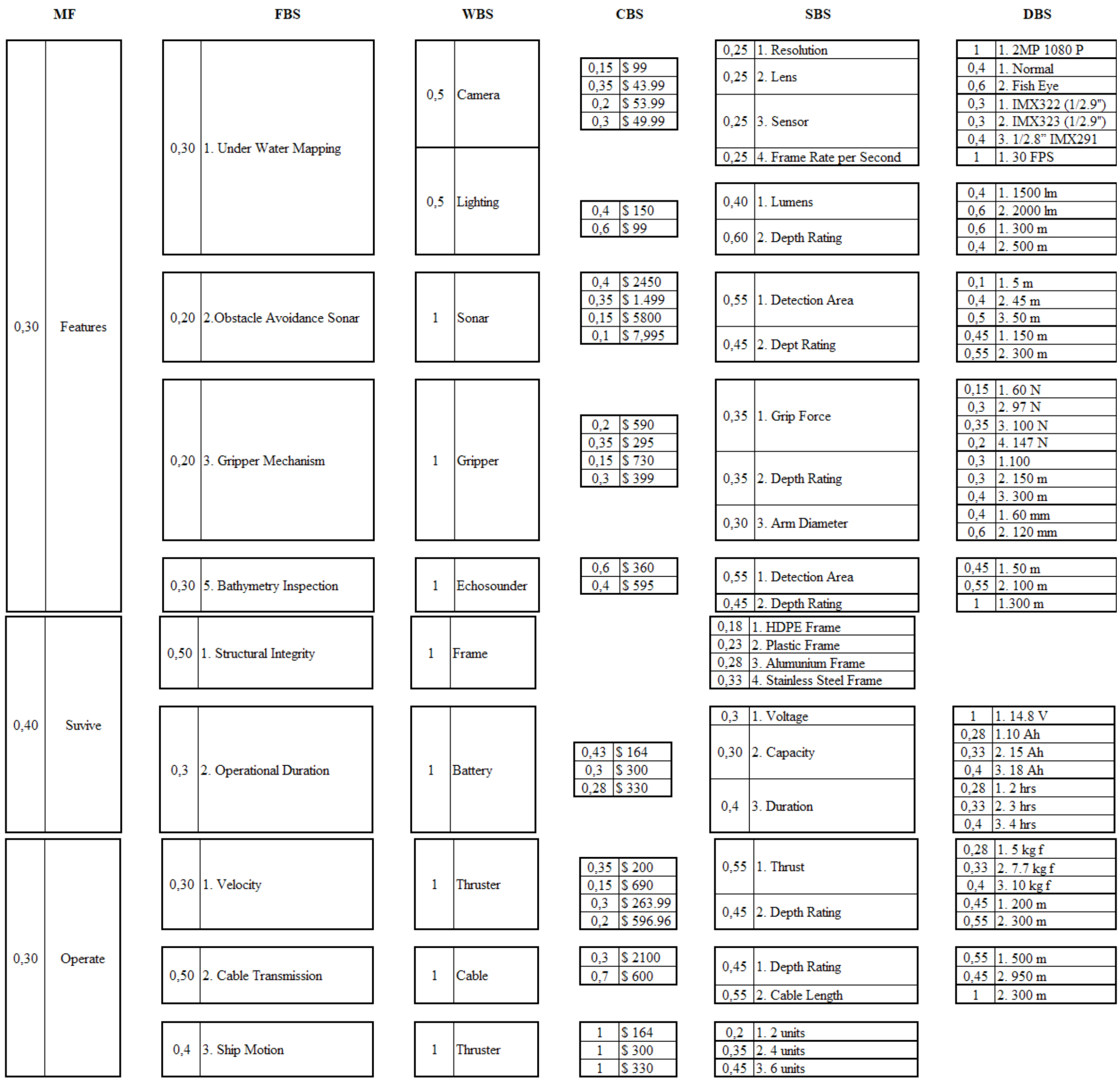

Figure 3 ROV Design Framework.

The limitation design produces a camera with 4 comparison price models, lighting with 2 comparison price models, sonar with 4 comparison price models, arm gripper with 4 comparison price models.

echosounder with 4 comparison price models, ROV frame with 4 comparison models, battery with 3 comparison price models, thruster with 4 comparison price models, cable with 2 comparison price models, and thruster with 3 comparison quantity models.

4. Discussion

The optimum design of ROV is determined by every breakdown structure and the full ROV system breakdown is shown in figure 3 above. The design will provide 4096 combination designs with different weight values. To simplify the iteration, the design process may only calculate the highest weight value for every comparison model. Then the optimum weight of ROV is 0,329 with the configuration shown in figure 4, figure 5, and figure 6 below.

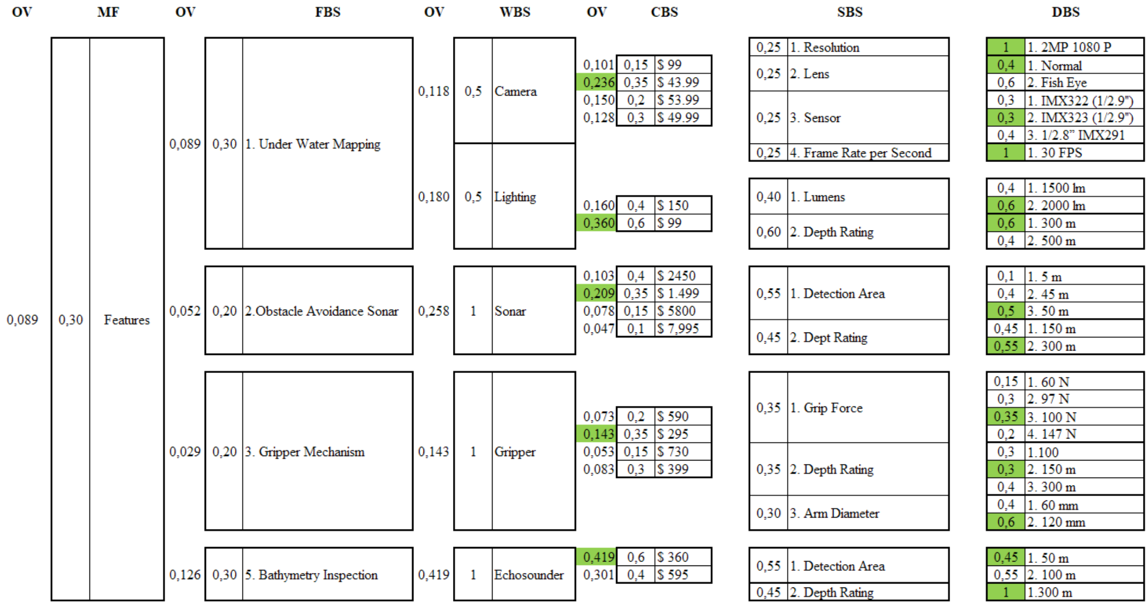

Figure 4 The Optimum Weight of Features Function.

From figure 4 above shows, the Feature function has the optimum weight at 0,089. Followed by each FBS has the optimum weight of 0,089 for the underwater mapping function, 0,052for the obstacle avoidance sensor function, 0,029 for the gripper mechanism function, and0,126 for the bathymetry inspection function. The highest weight for the camera is model number 2 with 0,236.

The optimum weight is highlighted with green color. The ROV camera will have a resolution of 2MP 1080 P, be equipped with a normal lens, have an IMX232 (1/2.9") sensor, and 30 FPS. The highest weight for lighting is model number 2 with 0,36. The light component will have 2000 lumens specifications and 300 m for the depth rating. The highest weight for lighting is model number 2 with 0,36. The lighting component will have 2000 lumens specifications and 300 m for the depth rating. The highest weight for the sonar is model number 2 with 0,209. The sonar component will have 50 m for detection area and300 m for depth rating. The highest weight for the gripper is model number 2 with 0,143.The gripper component will have 100 N for grip force, 150 m depth rating and120 mm for arm diameter. The highest weight for the echosounder is model number 1with 0,419. The echosounder component will have a 50 m detection area and 300 m for depth rating.

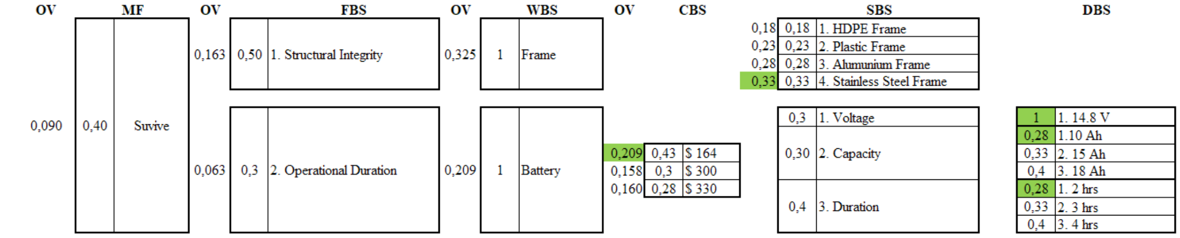

Figure 5 The Optimum Weight of Survive Function.

Figure 5 above shows the Survive function has the optimum weight at 0,090. Followed by each FBS has an optimum weight of 0,163 for structural integrity and 0,063 for the operational duration.
The highest weight for the frame is model number 2 stainless steel frame. The highest weight for the battery is model number 1. The battery component will have 14.8 in voltage,10Ah in battery capacity, and 2hrs for battery duration.

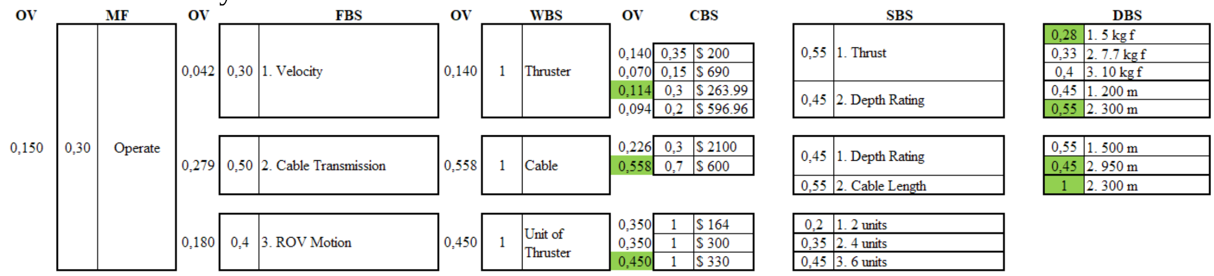

Figure 6 The Optimum Weight of Operate Function.

Figure 6 above shows, the Operate function has the optimum weight at 0,150. Followed by each FBS has the optimum weight at 0,042 for ROV velocity, 0,279 for cable transmission, and 0,18 for ROV motion.
The highest weight for the thruster is model number 3. The thruster component will have5 kg.f for thrust and 300 m for depth rating. The highest weight for cable is model number 2. The cable component will have a 950 depth rating and 300 m for cable length. The highest weight for the thruster is 6 units installation.

5. Conclusion

The optimization design has been carried out to determine ROV operational requirements in Madura Strait by Total-Based Method. ROV will be operated. From the analysis can be concluded only the component with the cheapest price will fulfill the specification requirement of ROV regarding the operational condition in the Madura Sea Strait Area. The ROV will be equipped with 2MP 1080P resolution for the camera, 2000 lumens for lighting, 50 m detection area for sonar and echosounder, 100 N grip force for Gripper, equipped with stainless steel frame, 2 hours long for the operational duration, 5kg.f for thruster, operated with cable 300 m long and equipped with the 6-unit thruster.

6. Acknowledgments

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7. References

[1] Tomiyama T, Gu P, Lutters D, Kind C and Kimura F 2009 *Manufacturing Technology* vol 58 issue 2 (Paris: CIRP) p 543
[2] Pugh S 1991 Total Design: Integrated Methods for Successful Product Engineering (New York :Addison-Wesley)

[3] Narayanan R, Spuzic S, Pundoor M, Bari S, Xing K and Fielke J 2013 *Proc. Conf. Australian Association for Engineering Education* (Australia : AAEE)
[4] Neri P, Dazzi N, Mangiarotti M and Palazzo L C 2004 *INCOSE International Symposium on Systems Effectiveness & Value Engineering (Toulouse)* (New York : Wiley) p 1738-1757
[5] Weatherall P, Marks K M, Jakobsson M, Schmitt T, Tani S, Arndt J E, Rovere M, Chayes D, Ferrini V and Wigley R 2015 *Earth and Space Science Volume 2 Issue 8* (America : AGU) p 331
[6] Papanikolaou A 2010 *Computer Aided Design Volume 42 Issue 11* (Athens : Elseveir) p 1028
[7] Hockberger W A 1996 Naval Engineers Journal (New York : Wiley) p 147