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Are the smallest fishing vessels the most sustainable?—trade-off analysis of sustainability attributes

Ingrid Bouwer Utne*

Department of Production and Quality Engineering, Norwegian University of Science and Technology (NTNU), NO 7491 Trondheim, Norway

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Abstract

This article discusses application of systems engineering principles and trade-off analysis of sustainability in the fishing fleet. Sustainability in the fishing fleet may be characterized by seven attributes measured by performance indicators. Evaluations show that the energy consumption is higher for the Norwegian ocean going fleet than the coastal fleet, whereas the opposite is the case for the number of fatalities. An important part of the systems engineering process is analysis and optimization of system alternatives. Thus, the main objective of the article is to investigate ranking of the sustainability attributes, which implies use of multi-attribute decision-making methods. The analytic hierarchy process was used to interview stakeholders to the fishing fleet about their preferences. The article concludes that if "accident risk" is weighted as the most important attribute, the smallest fishing vessels are not as sustainable as often claimed.

Keywords: Sustainability; Fishing fleet; Analytic hierarchy process

1. Introduction

Sustainable resource management is an important objective in most fisheries [1]. Overcapacity in the fishing fleet is one of the major threats to sustainability, because it leads to more effective fishing vessels and gear, which again increase the pressure on quota limits [2,3]. The main disciplines involved in fisheries management are bio-economics and social sciences. Still, overcapacity is also a technological problem, which implies a stronger integration of technological aspects into fisheries management [4]. Systems engineering has been introduced as a feasible process for handling sustainability issues in the fisheries [5,6].

The concept of sustainability is vague, and various interpretations appear in discussions about which fishing vessels are the most sustainable [7]. With respect to reductions of overcapacity in the fishing fleet, the system alternatives, which in this case are the different vessel groups, may give advantages and disadvantages. Fisheries management decisions impact a range of stakeholders with interests in the fisheries, and conflicting situations may occur, especially when considering complex issues like sustainability: one type of fishing technology may give higher income, but fewer employees. Another solution may improve safety, but also increase emissions of CO_2. In the systems engineering process, examining alternative solutions and finding the best one imply that trade-off analysis is carried out in an iterative loop until the best solution is found [5].

Trade-off analysis of sustainability in the Norwegian cod-fishing fleet is discussed in this article, as a further elaboration of systems engineering principles related to the fisheries [5]. The trade-off analysis is based on the results from a performance evaluation of the vessel groups in the cod-fisheries [6]. Multi-criteria decision analysis is evaluated on the basis of usefulness for assessing attributes of sustainability, and the analytic hierarchy process (AHP) is used to visualize the consequences of trade-off decisions, and to show the importance of stakeholder inclusion in the decision-making process. The article also discusses how sustainability in the fishing fleet may be measured and evaluated on a regular basis, by using an index

*Tel.: +47 982 22 465.
E-mail address: ingrid.b.utne@ntnu.no

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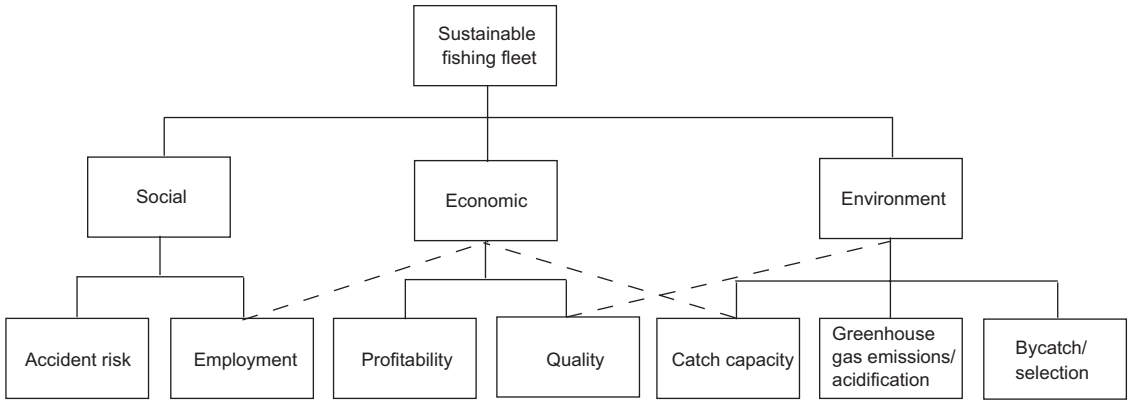

Fig. 1. Sustainability attributes of the cod-fishing fleet.

of sustainability. The system boundary is limited to the fishing vessels in the operational phase, representing the technological system interacting with the natural marine ecosystem.

1.1. Attributes of sustainability in the Norwegian cod-fishing fleet

Sustainable development may be characterized by three dimensions: the ecological, social, and economic dimension. In order to find out more about sustainability in the fishing fleet, the performance of the Norwegian cod-fishing fleet was evaluated at six attributes: accident risk, employment, profitability, quality of the fish meat, catch capacity (technical), and greenhouse gas (GHG) emissions/acidification [6], shown in Fig. 1. The selection of the attributes used to assess the various vessel groups is very important, because some attributes may favor one vessel group at the expense of others. The attributes were selected based on government objectives of sustainable resource management found in Table 1.

From the system boundaries, it may be questioned if bycatch/selection is a relevant attribute since it mainly impacts on the natural marine ecosystem. Nevertheless, bycatch may affect profitability of the fishing vessel, and selection may impact fuel consumption. Bycatch/selection has also been considered in other environmental analyses of fisheries [8].

The main results from the system evaluation are summarized in Table 2. The attributes have been evaluated by using performance indicators. The attribute "accident risk" is measured by the fatal accident rate (FAR), and "employment" is measured by "average man-labor years per vessel". "Profitability" is measured by "earning capacity, NOK/kg fish", and "quality" is assessed by damage to the fish meat by the catching gear, and prices paid per kg fish. "Catch capacity" is measured by technical parameters, such as length and gross tonnage weight in the statistics from the Directorate of the Fisheries [11–13], and "GHG emissions/acidification" is measured by the indicator "kg fuel/kg fish".

Table 1
The attributes related to objectives of sustainable fisheries management [6,9,10]

Attributes	Objectives
Accident risk	Reduce accident risk
Employment	Maintain rural settlement
Profitability	Increase profitability
Quality	Increase quality of fish meat/reduce damage
Catch capacity	Reduce overcapacity in the fishing fleet
GHG emissions/ acidification[a]	Reduce emissions
Bycatch/selection	Reduce bycatch/improve selection

[a]This attribute is related to emissions of CO_2 and NO_x.

Table 2
The results from the system evaluation of the vessel groups in the Norwegian cod-fisheries [6]

Attributes and performance indicators	A	B	C	D	E
Accident risk, 1998-2003, FAR[a]	152	35	13	12	19
Employment, 2004, average man-labor years/vessel	1.6	3.8	12.8	27.6	14.3
Profitability, 2004, earning capacity, NOK/kg fish	4.56	3.39	3.59	2.25	2.82
Quality, 1–5 (5 is best)	5	3	5	3	3
Catch capacity, 2004, 1–5 (5 is best)	1	2	3	5	4
GHG emissions/ acidification, 2004, kg fuel/kg fish	0.15	0.15	0.32	0.47	0.54

[a]Fatal accident rate (FAR) is the mean number of fatalities per 10^8 h of exposure.

Vessel groups A–E are in accordance with the cod-fishing vessel groups in the statistics from the Norwegian Directorate of the Fisheries from 2003 and onwards [11–13] according to length (ℓ) and type:

A: Small coastal vessels (net, hand line, Danish seine, long-lining), $\ell < 15$ m.