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Target Systems and Decision-Making to Increase Production Sustainability

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Abstract

Many industrial companies are trying to improve their operation's sustainability. However, these efforts towards change are usually governed by economic considerations. This serves to neglect or at least diminish the perceivable relevance of ecologic or social consequences for investigated alternatives. This paper discusses the implications of multi-criterial target systems which extend the scope of considerations beyond economics to support the realisation of proactive environmental strategies. A special focus is set on the definition of targets as well as decision-making in brown-field planning projects. The findings are applied in a simulation-based study on the parameterisation of an energy-sensitive production control strategy.

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Keywords: Target systems; Brown-field planning projects; Sustainability; Energy-sensitive production strategy; Multi-objective genetic algorithm; NSGA-II

1. Introduction

Legislators across the world are pushing for the use of clean energy, high energy efficiency and ergonomic work environments. Similarly, customers and shareholders expect companies to work towards sustainable operations. Following the UN definition of the term, this includes ecologic, economic and social targets [1]. Yet, actual decision-making processes are usually governed by economic considerations. Still, the environmental strategy of an organisation has tremendous influence on its approach towards sustainable change and can be classified on a scale from defensive to proactive [2,3]. Defensive strategies regard environmental aspects as a constraint imposed by official bodies, while proactive understand them as an autonomous target figure. In between these two, accommodative approaches can be identified, where environmental actions surpass legal demands to create economic advantages.

Decision-making processes which focus too much on the economics are problematic because important ecologic and social factors may be disregarded or need to be assessed on a monetary basis. Especially in factory planning projects, this serves to neglect or diminish the consideration of non-economic consequences by decision makers. At the same time, decision-makers occupying different roles in companies will focus on different target figures.

Emphasising ecologic and social aspects in the decision-making process can serve to support the realisation of proactive environmental strategies and to foster change towards more sustainable production operations. This paper discusses how multi-criterial target systems can be systematically included in brown-field factory planning projects. Arguably, this approach may also be applied in green-field projects. Yet, brown-field was focussed upon for its emphasis on less structural change and greater cost pressure. A potential decision problem in such projects is the selection and optimal parameterisation of an energy-sensitive production control strategy to increase sustainability. This is hereafter exemplified using a case study from the automotive industry, specifically the body shop, which is introduced in Section 2. In the following, some general considerations on decision-making theory as well as the definition of target systems will be introduced before a case-study-specific target system is presented and possible decision-making procedures are outlined. Section 4 discusses how the initial problem was then investigated using material flow simulation and multi-objective genetic algorithms. The corresponding results are also discussed in this section.

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2. Problem definition and case study

Car body shops in countries with high labour costs make use of highly automated equipment which is designed and operated for maximum quality and productivity. Nonetheless, efficiency improvements at minimum cost are expected and sought on a regular basis. A promising approach can be the introduction of energy-sensitive production control strategies. Their implementation is associated with low costs, as primarily organisational changes are needed, but also poses high risks concerning process disruptions. Yet, they can serve to increase the sustainability of a production site if carefully planned.

Deciding on the most suitable strategy to implement and the parameters it should use is, however, a difficile task. This is hereafter exemplified in a case study which investigates a car body shop in a common fish bone structure with 4 manual assembly stations and a finishing area (light tunnel) on the main production line. The assembly stations are supplied by 2 fully automated facilities (subsystems) each, which produce front doors for 3-door variants (FD3), front and rear doors for 5-door variants (FD5/RD5), bonnets, tailgates and wings. All of these subsystems are decoupled from the mainline through buffers. Fig. 1 depicts the corresponding layout structure.

For the operation of the subsystems two energy-sensitive production strategy have been suggested: eniKanban [5] and ConEnIP [6]. eniKanban is, in essence, a Kanban solution which links production control to equipment control. The idea is to operate the equipment in a way that joins multiple short idle periods to fewer but longer ones, during which energy savings can be achieved by shutting down machinery. This is facilitated by stopping production and switching off machines and infrastructure when buffers are full and starting them when a lower threshold is reached. Both the buffer's size and minimal content must be parameterised per subsystem.

ConEnIP, on the other hand, tries to limit the necessary power input of the entire system. For this purpose, a queuing system for production jobs is introduced which will only allow production facilities (e.g. subsystems) to operate when a job and sufficient power capacity are available. Once an entity finishes all jobs it is shut down for a minimal period of time, freeing power capacity. Jobs are created and added to queue when a certain amount of buffered parts have been used (i.e. left the buffer). The parameters of this strategy are the job size and number of jobs per subsystem (the product of which is the buffer size of the decoupling buffer), the priority strategy for the ConEnIP job queue, the minimal shutdown time for subsystems and the maximal power to be consumed by the entire production system. The latter can be segmented over time, i.e. for the day (6:00–20:59) and the night (21:00–5:59).

In order to decide on the strategy and the respective parameters, the above system is simulated to collect data for calculating suitable target figures according to the target system. Parameters of the strategies are integer numbers from within a predetermined range with equidistant step size (e.g. buffer size = n, n ϵ {4, 6, 8, 10}). The use of simulation is preferable as it ensures a low probability for process disruptions during the testing and implementation of a strategy.

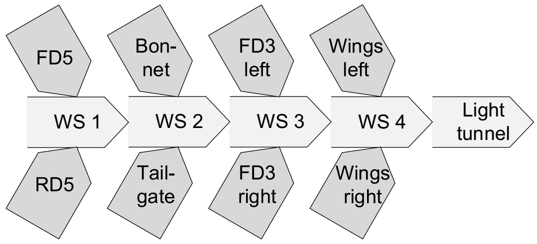

Fig. 1. Structure of the exemplary production facility [4].

3. Decision theory-based approach for decision-making

In order to reach greater sustainability in complex problems some insights into decision theory are valuable. Hence, a brief introduction into the matter is presented hereafter, followed by a case-study-driven discussion of target systems and decision-making procedures.

3.1. Basics from decision theory

The description of the underlying problem reveals its complexity: Several target criteria are relevant, it has to be decided on an energy-sensitive production strategy and its concrete implementation by setting the parameters listed in the previous section and the results are dependent on various uncertain influencing factors such as the intended output, factor prices etc. For structuring such complex decision fields a drawback on fundamental thoughts of decision theory is meaningful [7]. According to decision theory, in a systematic decision-making process the alternatives have to be evaluated with respect to the one or more relevant target criteria and against the background of one or more scenarios bundling the expected outcomes of relevant influencing factors from inside and outside a company. As a central part of this evaluation, the expected effects of the alternatives on the target criteria have to be identified, analysed and forecast by using implicit or explicit result functions that model the relationship between alternatives, influencing factors and target criteria. Concluding, target criteria, alternatives, scenarios (influencing factors) as well as result functions and their results are constitutive elements of decision problems as well as the models representing them. Since the target system is the focal point of all problem solving activities concerning these elements (including the evaluation of alternatives), the forming of a target system is focused in the next step.

3.2. Forming a target system

In the introduction it was argued that contemporary production strategies should be directed towards the criteria of sustainability. Thus, a target system for brown-field planning should comprise the economic as well as ecological and social targets that are influenced by the alternatives under consideration. Since technical targets such as capacity and productivity are also often discussed in the context of decisions on production strategies, the question arises how such targets are coupled with the economic, ecological and social targets focused by the concept of sustainability. Fig. 2 presents the an-