

Esra Büyüktahtakın (from left), J. Cole Smith and Joseph C. Hartman helped devise a decision-making tool to aid managers in replacing assets.

Mixed-integer programming for asset replacement

The management of capital assets is vital to the efficiency and profitability of operations in any industry. Examples of capital assets include but are not limited to drilling machines required to produce parts, healthcare imaging equipment that provide scanning services, trailers that carry goods, or computers that store and process data.

A decision often faced by managers is the replacement of assets at the minimum possible cost while continuing operations to meet customer demand. Assets are usually economically interdependent due to budget constraints that limit the number of new assets that can be purchased, demand constraints that require a number of assets in operation, and fixed replacement costs that promote combined replacement actions through economies of scale.

There are a number of factors motivating the replacement of capital assets. These factors include increased operating and maintenance costs and reduced capacity caused by deterioration of the currently owned asset (defender) or technological advances that make newer assets (challengers) more efficient to operate with lower operating and maintenance costs. The parallel replacement problem under economies of scale (PRES) is concerned with determining the minimum-cost replacement schedule (periodic keep-and-replace decisions) of each individual asset in a group of assets that operate in parallel and are subject to fixed and variable costs.

This problem could be further complicated by considering multiple asset types, or challengers, that are available for replacement (MPRES). The multiple challenger case is interesting, and its analysis is important because assets often have multiple suppliers (i.e., General Electric vs. Siemens, Boeing vs. Airbus, General Motors vs. Toyota, etc.).

Esra Büyüktahtakın of Wichita State University, J. Cole Smith of Clemson University, Joseph C. Hartman of the University of Massachusetts Lowell, and Shangyuan Luo from UBS AG address this problem in their paper "Parallel Asset Replacement Problem under Economies of Scale with Multiple Challengers." The authors prove that PRES is NP-hard in the strong sense, implying that it is a very difficult problem to optimize. The authors then focus on developing algorithms for solving a mixed-integer programming formulation of PRES using valid inequalities. Computational results show that valid inequalities significantly help to reduce the optimality gap for the MPRES, especially for large-scale instances, and thus are effective in solving problems that arise in real industrial settings.

The ability to solve problems of parallel asset replacement with multiple challengers is critical in industry today, as managers often must trade off the value between suppliers. For example, a fleet manager may be looking to replace lightweight trucks, which can come from a variety of manufacturers (e.g., Ford, Chevy, Toyota). The proposed model can simultaneously evaluate the different investment options according to costs.

This can then serve as a critical input to the replacement decision. Note that the model is general in that the type of asset is irrelevant – the user must merely be able to define the asset according to its replacement and operating costs.

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