European Journal of Operational Research 207 (2010) 958–970

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Integrated planning of transportation and recycling for multiple plants based on process simulation

Magnus Fröhling *, Frank Schwaderer, Hauke Bartusch, Otto Rentz

Karlsruhe Institute of Technology (KIT), Institute for Industrial Production (IIP), Hertzstraße 16, D-76187 Karlsruhe, Germany

ARTICLE INFO

Article history:
Received 2 August 2008
Accepted 28 April 2010
Available online 9 May 2010

Keywords:
Closed-loop supply chains
Process industries
Process modelling
Operational planning
Integrated planning
Blending

ABSTRACT

By-products accrue in all stages of industrial production networks. Legal requirements, shortening of primary resources and their increasing prices make their recycling more and more important. For the re-integration into the economic cycle the scope of common supply chain management is enlarged and so-called closed-loop supply chains with adapted and new planning tasks are developed. In process industries this requires a detailed modelling of the recycling processes. This is of special relevance for operational planning tasks in which an optimal usage of a given production system is envisaged. This contribution presents an integrated planning approach for a real-world case study from the zinc industry to achieve such an adequate process modelling. We consider the planning problem of a company that operates four metallurgical recycling plants and has to allocate residues from different sources to these recycling sites. The allocation determines the raw material mix used in the plants. This blending has an effect on the transportation costs and the costs and revenues of the individual technical processes in the recycling plants. Therefore in this problem transportation and recycling planning for multiple sites have to be regarded in an integrated way. The necessary detailed process modelling is achieved by the use of a flowsheet process simulation system to model each recycling plant individually. The models are used to derive linear input–output functions by multiple linear regression analyses. These are used in an integrated planning model to calculate the decision-relevant input and output flows that are dependent upon the allocation of the residues to the recycling sites. The model is embedded in a decision support system for the operational use. An example application and sensitivity analyses demonstrate and validate the approach and its potentials. The approach is transferable to other recycling processes as well as to other processes in process industries.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

The legal framework in the European Union and Germany, as well as high resource and energy prices, limited and expensive landfill capacities, moral and ethical responsibility (Seitz, 2007), and also customers' demands or refusals of products (see, e.g. Toffel, 2004; Prahinski and Kocabasoglu, 2006), have led to a growing importance of take-back and recycling. The value of by-products and end-of-life products that contain valuable or scarce materials is increased as primary resources are depleted. Re-integrating these into the material flow creates a closed-loop supply chain. With the efforts to establish a closed-loop economy, common supply chain management has to be further developed towards closed-loop supply chain management. The scope of the planning is enlarged to backward material flows and further actors such as specialised recycling companies. Common supply chain management tasks are adapted to the specific needs of the closed-loop supply chain and new planning tasks have to be considered (Dyckhoff et al., 2004). Additional tasks are product or material acquisition (e.g. collecting), reverse logistics – the isolated managing of the return flows (Krikke et al., 2004) – testing, sorting and disposition, re-processing, selling and redistribution of the products and materials (see, e.g. Guide et al., 2003). Both, strategic and operational planning tasks are affected by this.

The literature in the field of closed-loop supply chain management and reverse logistics has become more comprehensive within the last few years. Nevertheless, works dealing with operational planning tasks, especially in the process industries, remain scarce. While the network or production structures are regarded as fixed on the operational level, the adaptation of the process operation to changing environments through different modes of operations or other raw material blends influence material and energy flows significantly. These are very often the dominating economic drivers

* Corresponding author. Tel.: +49 (0)721 608 4400; fax: +49 (0)721 608 4682.
E-mail addresses: magnus.froehling@kit.edu (M. Fröhling), frank.schwaderer@kit.edu (F. Schwaderer), hauke.bartusch@kit.edu (H. Bartusch), otto.rentz@kit.edu (O. Rentz).

0377-2217/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ejor.2010.04.031

of the processes. Especially with the current extremely volatile prices for raw materials and products short-time adaptations are often crucial. Therefore operational planning requires an adequate modelling of the technical systems. This has to cover especially a detailed modelling of the input and output material flows, the conversion processes and the impacts of changes in each technical facility on costs and revenues.

This paper further develops closed-loop supply chain planning systems by elaborating and implementing an operational planning approach for the integrated transport and blending planning for multiple recycling plants that comprises a detailed modelling of each single recycling process. To ensure and demonstrate the practical relevance and to validate the approach it is developed in cooperation with a recycling company from the zinc industry and applied to real planning scenarios. A transfer of the methodology to other applications is possible.

The study is structured as follows: The next section describes the case study of the recycling company and characterises the planning problem. Afterwards an overview of the related literature in this field is given. Then we describe the development of the decision support system for the planning problem, explaining the necessity of detailed process modelling and showing especially how we integrate such process modelling in an integrated planning model for our case study. For demonstration and validation purposes, the system is applied exemplarily to different planning scenarios and compared to a benchmark problem. In sensitivity analyses the stability of the solutions under changing parameter values is analysed. Finally, we draw conclusions and provide an outlook on potential further developments and transfer possibilities.

Table 1
Typical chemical composition of EAF dust.

Iron-oxide (FeO)	Zinc-oxide (ZnO)	Calcium-oxide (CaO)	Lead-oxide (PbO)	Silicium-dioxide (SiO_2)
20–38%	18–35%	6–9%	2–7%	3–5%

2. Operational planning in the case of zinc recycling in Waelz Kilns

In secondary production of steel, so-called electric arc furnaces (EAFs) melt steel scrap to regain steel. Due to the use of coated steel, for example in automobile production, the steel scrap often contains zinc. In Europe approximately 170 EAFs produce around 80 million tons of steel per year (Wirtschaftsvereinigung Stahl, 2009). With every ton of steel produced this way, 10–15 kg of a zinc-containing ferrous residue, so-called EAF dust, accrue (Rentz et al., 1995). This leads to approximately 1 million tons of EAF dust in Europe per year. According to European law, this dust has to be utilised. Its high zinc content (see the sample composition in Table 1) makes recycling economically attractive. As internal recycling options for these dusts can be problematic in terms of energy efficiency and enrichment of problematic substances, the supply chain is closed by specialised external recycling processes for the utilisation of these dusts.

The reference company of our case study, BEFESA Steel Services GmbH, Duisburg, is a specialised reverse supply chain player. They operate four so-called Waelz kiln plants to recycle EAF dusts and other zinc-containing residues. Being legally independent of EAF operators and zinc electrolysis plants, which are the customers for the recycled material, the company follows economic aims. In the recycling plants the residues are firstly mixed. This blend is then heated in the Waelz kilns. After reduction, vaporisation and re-oxidisation, the zinc leaves the kiln with the process gas and is separated in a gas cleaning facility. Afterwards, the produced zinc oxide, the so-called Waelz oxide, can be processed further in leaching steps to meet quality requirements before it is sold to the zinc industry as secondary raw material. Waelz slag is tapped at the bottom of the kiln as by-product and used in landfill building. Thus, the Waelz process re-integrates the zinc into the material flow loop (see, Fig. 1).

From an economic point of view, the case study can be described as follows: The company receives a treatment charge from the suppliers of the zinc-containing residues, for example the EAF

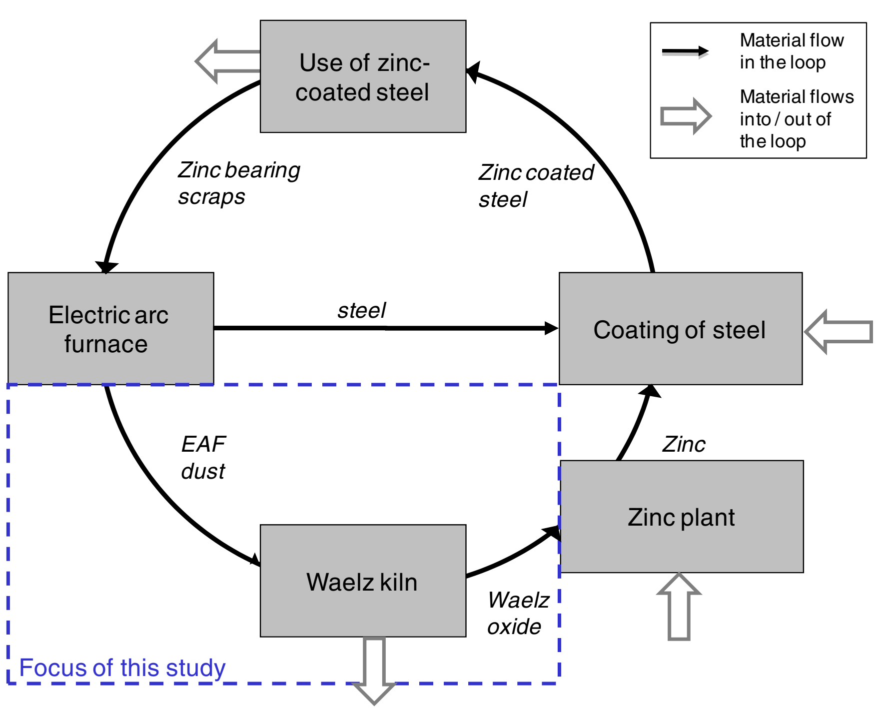

Fig. 1. The considered part of the material flow loop of the iron and steel and zinc industry (simplified).

Download English Version:

https://daneshyari.com/en/article/478629

Download Persian Version:

https://daneshyari.com/article/478629

Daneshyari.com