European Journal of Operational Research 000 (2018) 1–23

Contents lists available at ScienceDirect

European Journal of Operational Research

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

Innovative Applications of O.R.

A matheuristic decomposition approach for the scheduling of a single-source and multiple destinations pipeline system

William Hitoshi Tsunoda Meira[a], Leandro Magatão[a,*], Susana Relvas[b], Ana Paula Barbosa-Póvoa[b], Flávio Neves Jr.[a], Lúcia V. R. Arruda[a]

[a] CPGEI-UTFPR - Graduate Program in Electrical and Computer Engineering, Universidade Tecnológica Federal do Paraná, Curitiba, Paraná 80230-901, Brazil
[b] CEG-IST - Centre for Management Studies, Instituto Superior Técnico, Universidade de Lisboa, Lisbon 1049-001, Portugal

ARTICLE INFO

Article history:
Received 3 August 2017
Accepted 12 January 2018
Available online xxx

Keywords:
Distribution
Multiproduct pipeline
Scheduling
Decomposition approach
Mixed integer linear programming

ABSTRACT

An improvement on the scheduling of pumping and delivery operations in an installed pipeline network can lead to considerable profits to the using companies, such as oil companies. This paper proposes a decomposition approach that integrates heuristic procedures and mixed integer linear programming (MILP) models, a matheuristic, to solve the long-term scheduling of a pipeline system, which connects a single-source to multiple distribution centers. The approach provides a rigorous inventory management and flow rate control taking into account several operational aspects, such as simultaneous deliveries, and prespecified periods of tank maintenance and pipeline maintenance. To validate the developed approach, two case studies were devised. In case study 1, several instances of an illustrative network were solved and case study 2 addressed three examples of a real-world network: base instance; extended instance with maintenance periods; and model performance tests. Valid solutions that can be operationally implemented were obtained for all executions in a reasonable computational time. Detailed discussions of the obtained solutions are presented and indicate an inventory control in accordance with operational requirements.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

One of the major challenges in the oil industry is the management of the transportation activities of petroleum products from the refineries to the distribution centers. The transport is usually made through diverse means, such as: trucks, trains, vessels, and pipelines. In many countries, most part of their oil derivatives production (e.g. gasoline, diesel, kerosene, naphtha) are distributed through pipelines, justified because of the high volume capacity, reliability, economy, and safety compared to other means (Sasikumar, Ravi Prakash, Patil, & Ramani, 1997). Currently, most of the planning and scheduling activities in pipeline systems are decided by a group of specialists (schedulers), where their decisions are based on past experiences and manual calculations. In order to aid the decision-making process, optimization techniques have received great interest from the oil companies, where any improvement of the process, or better usage of the available resources, may increase considerably their profits (Boschetto et al., 2010).

A typical pipeline network topology consists of a single-source (a refinery) connecting one or more distribution centers (DCs) with a straight multiproduct pipeline. More complex topologies are possible, including systems with multiple sources (Cafaro & Cerdá, 2009), DCs that can act also as inputs (dual purpose) (Cafaro, Cafaro, Méndez, & Cerdá, 2015b; Mostafaei & Castro, 2017; Mostafaei, Castro, & Ghaffari-Hadigheh, 2016), multiple pipelines that configure tree-structures (Cafaro & Cerdá, 2011; MirHassani & Jahromi, 2011) or mesh-structures (Magatão, Magatão, Neves-Jr, & Arruda, 2015; Magatão et al., 2012; Polli, Magatão, Magatão, Neves-Jr, & Arruda, 2017). In this paper, we focus on the problem with one source and multiple destinations. At this topology, a common transport operation consists of a refinery pumping oil product batches, without any separator device, into the straight pipeline in order to attend the local demand of the connected DCs at the right time and the lowest possible cost. The interface of two consecutive batches of different products generates a contaminated volume. If this volume is substantially high, then the sequence is considered a forbidden operation. The scheduling of a multiproduct pipeline is a hard problem, whose complexity is NP-complete (Jittamai, 2004). It involves many operational restrictions, such as inventory control at DCs, demand attendance, flow rate control, product restrictions, simultaneous deliveries.

* Corresponding author.
E-mail address: magatao@utfpr.edu.br (L. Magatão).

https://doi.org/10.1016/j.ejor.2018.01.032
0377-2217/© 2018 Elsevier B.V. All rights reserved.

Please cite this article as: W.H.T. Meira et al., A matheuristic decomposition approach for the scheduling of a single-source and multiple destinations pipeline system, European Journal of Operational Research (2018), https://doi.org/10.1016/j.ejor.2018.01.032

Nomenclature

Indices/sets

$e \in E$ — set of events
$i, i' \in I$ — set of intervals. The interval i starts at $e = i - 1$ and ends at $e = i$
$p, p' \in P$ — set of products (oil derivatives)
$n \in N$ — set of distribution centers (DCs)
$\{n, p\} \in NP$ — sparse set containing the tuple $\{n, p\}$; node n being a DC where product p can be delivered. Not necessarily all products can be delivered to all DCs
$\{n, p, e\} \in NPE$ — sparse set containing the tuple $\{n, p, e\}$, which associates every element of $\{n, p\} \in NP$ to every $e \in E$
$\{n, p, i\} \in NPI$ — sparse set containing the tuple $\{n, p, i\}$, which associates every element of $\{n, p\} \in NP$ to every $i \in I$
$b, b' \in B$ — set of initialization and allocated batches indexes. The first index is the closest batch to the last DC, increasing a unit for each following initialization batch and then the allocated batches as each one enters the network
$ib \in B^{init}$ — set of only initialization batches indexes. This set is a subset of all batches ($B^{init} \subset B$)
$\{b, e\} \in BE$ — set containing the tuple $\{b, e\}$, which combines each batch index b with an event e
$\{b, i\} \in BI$ — set containing the tuple $\{b, i\}$, which associates each batch index b with an interval i
$\{b, e, n\} \in BEN$ — set containing the tuple $\{b, e, n\}$, which associates each batch index b with an event e and a DC n
$\{b, i, n\} \in BIN$ — set containing the tuple $\{b, i, n\}$, which associates each batch index b with an interval i and a DC n

Parameters

$U \gg 0$ — upper bound value (e.g. $U = 10^6$)
$L \ll 0$ — lower bound value (e.g. $L = -U$)
ϵ — small constant value used to avoid equalities (e.g. $\epsilon = 10^{-4}$)
T_i — duration of the interval i (hour)
IP_p — binary parameter indicating if product p is being pumped from the refinery at the initial event ($e = 0$)
IV_p — initial volume of product p being pumped from the refinery at the initial event ($e = 0$). It is greater than 0 only for the product p where $IP_p = 1$ (vu)
VC_n — volumetric coordinate of DC n from zero coordinate, $n = 0$ (vu)
$Fp_{p,i}^{min}$ — minimum pumping flow rate of product p during the interval i (vu/hour)
$Fp_{p,i}^{max}$ — maximum pumping flow rate of product p during the interval i (vu/hour)
$Fd_{n,p}^{min}$ — minimum delivery flow rate of product p at the DC n (vu/hour)
$Fd_{n,p}^{max}$ — maximum delivery flow rate of product p at the DC n (vu/hour)
Fs_p^{min} — minimum segment passage flow rate of product p for the considered pipeline segment during the actual SM iteration (vu/hour)
Fs_p^{max} — maximum segment passage flow rate of product p for the considered pipeline segment during the actual SM iteration (vu/hour)
Lb_p^{min} — minimum batch pumping size (vu)
Lb_p^{max} — maximum batch pumping size (vu)
Ld_p^{min} — minimum delivery size (vu)
$PP_{p,p'}$ — matrix of forbidden pumping sequences between two consecutive products p and p'
$Dem_{n,p,i}$ — demand of product p in DC n during the interval i (vu)
$Rec_{n,p,i}$ — volume of product p being received in DC n during the interval i (vu). The values are obtained during the initialization batches simplification in the ASM and also in the SM
B_e^{last} — indicates the index of the closest batch b to the upstream DC at the event e, which also means the last batch pumped into the segment
B_i^{pass} — indicates the index of batch b passing along the upstream DC during interval i
V_i^{pass} — volume of the batch part B_i^{pass} passing along the upstream DC during interval i (vu)
F_i^{pass} — flow rate of the batch part B_i^{pass} passing along the upstream DC during interval i (vu/hour)
P_b — product p of the batch b
V_{ib}^{init} — volume of the initialization batch ib at the beginning of the horizon (vu)
$HPos_{ib}^{init}$ — volumetric coordinate of the initialization batch head ib at the beginning of the horizon (vu)
$ID_{n,p}$ — initial inventory volume of product p in DC n (vu)
$ID_{n,p,e}^{empty}$ — volume considered empty for the aggregate inventory storage of product p in DC n at the event e (vu)
$ID_{n,p,e}^{cap}$ — volume capacity of the aggregate inventory storage of product p in DC n at the event e (vu)
$ID_{n,p,e}^{min}$ — minimum operational level for the aggregate inventory storage of product p in DC n at the event e (vu)
$ID_{n,p,e}^{max}$ — maximum operational level for the aggregate inventory storage of product p in DC n at the event e (vu)
$ID_{n,p,e}^{mintg}$ — minimum target level for the aggregate inventory storage of product p in DC n at the event e (vu)
$ID_{n,p,e}^{maxtg}$ — maximum target level for the aggregate inventory storage of product p in DC n at the event e (vu)
Cid^{emp} — penalty cost per vu of inventory empty violation at an event
Cid^{cap} — penalty cost per vu of inventory capacity violation at an event
Cid^{min} — penalty cost per vu of inventory minimum operational level violation at an event
Cid^{max} — penalty cost per vu of inventory maximum operational level violation at an event
Cid^{mintg} — penalty cost per vu of inventory minimum target level violation at an event
Cid^{maxtg} — penalty cost per vu of inventory maximum target level violation at an event
Cfr^{lmean} — penalty cost per vu/hour lower violation of the mean flow rate at an event
Cfr^{umean} — penalty cost per vu/hour upper violation of the mean flow rate at an event
Cfr^{min} — penalty cost per vu/hour of flow rate minimum flow violation at an event
Cfr^{max} — penalty cost per vu/hour of flow rate maximum flow violation at an event
Cfr^{ldiff} — penalty cost per vu/hour due the lower difference of flow rate compared to the last interval

Please cite this article as: W.H.T. Meira et al., A matheuristic decomposition approach for the scheduling of a single-source and multiple destinations pipeline system, European Journal of Operational Research (2018), https://doi.org/10.1016/j.ejor.2018.01.032

Download English Version:

https://daneshyari.com/en/article/6894843

Download Persian Version:

https://daneshyari.com/article/6894843

Daneshyari.com