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A MILP Planning Model for a Real-world Multiproduct Pipeline Network

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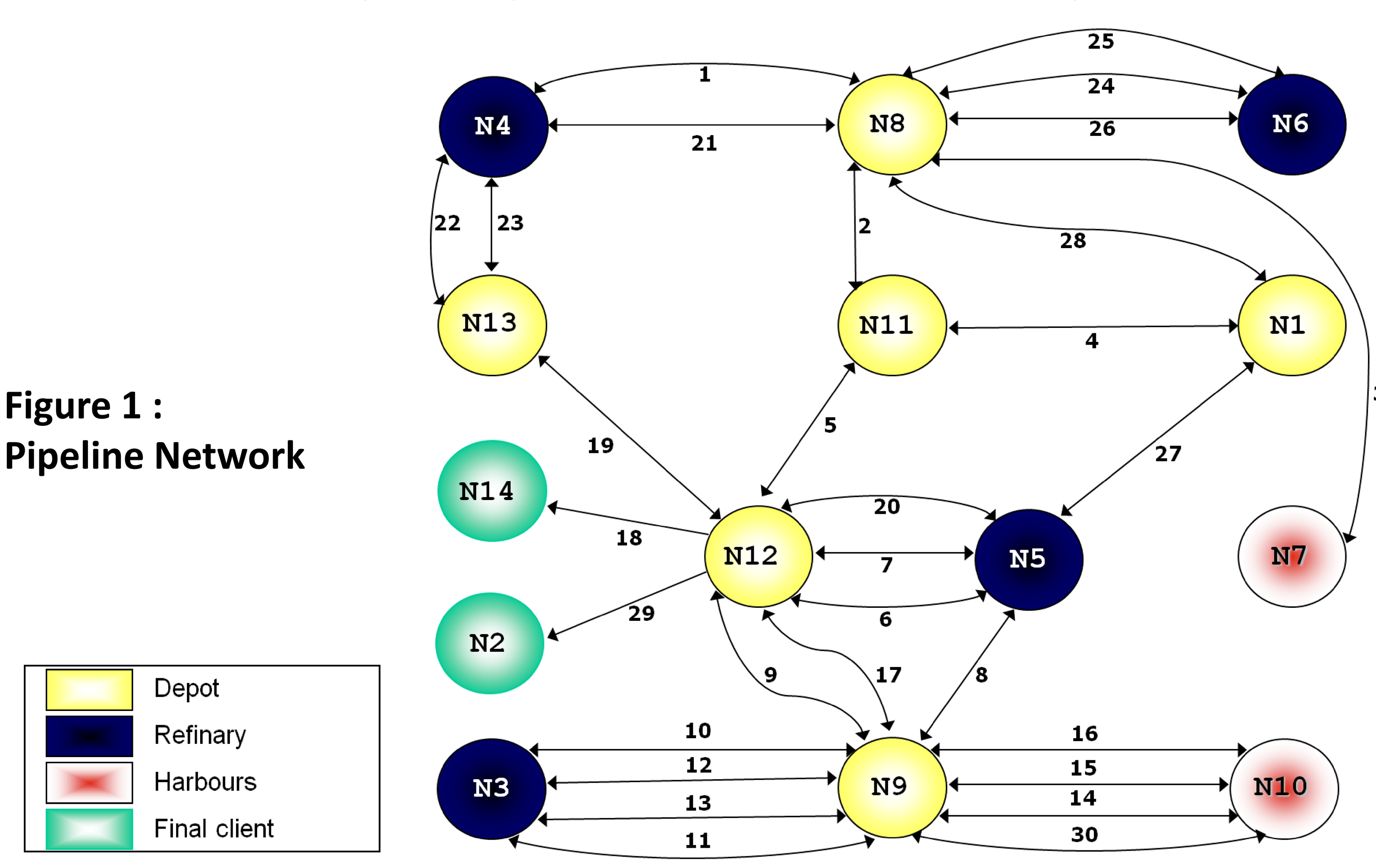
1. Introduction

The current work presents a planning model to address the allocation and transportation of products among different producing/consuming areas in a complex pipeline network. In this way, the logistics of pipelines is performed respecting a series operational constraints. In a subsequent step, the proposed model can be used in a collaborative way with the scheduling architecture proposed by Boschetto et al. (2010) to obtain the complete pipeline network scheduling.

2. Problem Statement

In the addressed real-world multiproduct pipeline network (Fig. 1), the transport of each product involves the management of a set of specific tank farms, according to the considered areas. The inventory management must respect inventory operational limits. Refineries (N3, N4, N5, and N6) produce or consume products while depots (N1, N8, N9, N11, N12, and N13) can receive, deliver or consume the stored products. Harbours (N7 and N10) can import or export the oil derivatives. Two areas are final clients (N2 and N14) and only receive products. The pipelines can be shared by 34 oil derivatives and the products can be sent from an origin area to various destination areas, as can be received in a destination area from different origin areas. Also, the best route (involving areas and pipelines) for each transported product has to be defined by the model.

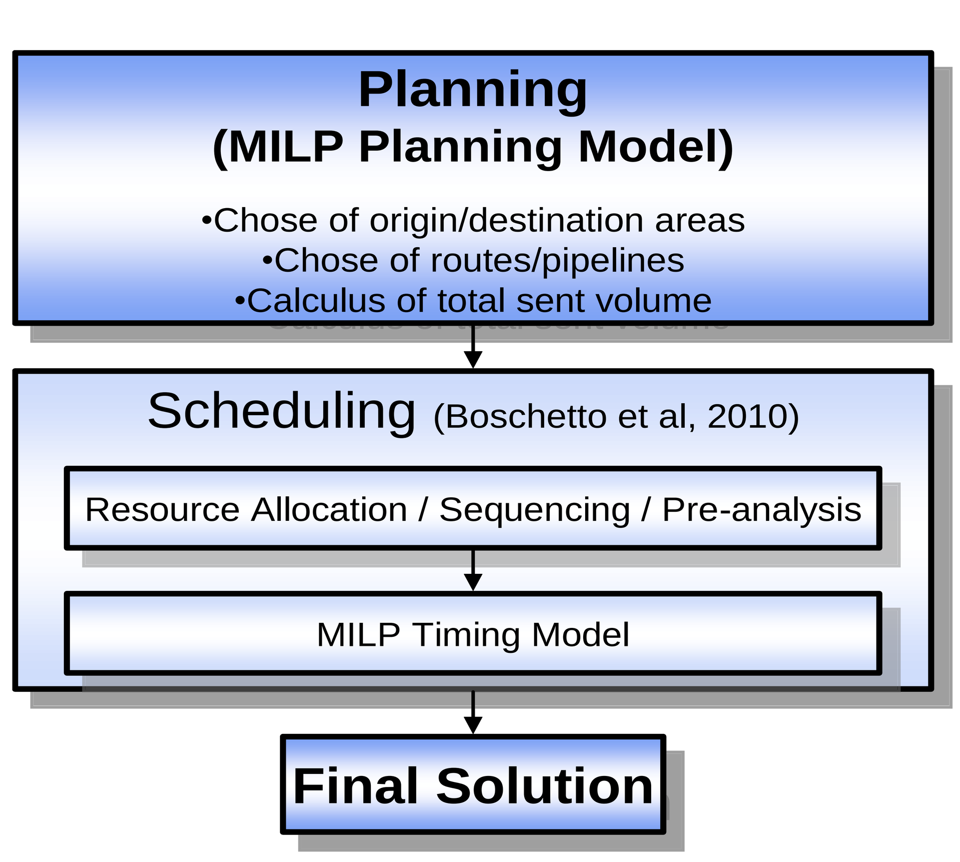
Figure 1 :
Pipeline Network



3. Optimisation Structure

In this work, a decomposition method is proposed in order to obtain medium-term problem solutions. The decomposition is based on two sequential steps. The results supplied by the MILP planning model are used as parameters in a scheduling phase (Fig. 2). In this way, the volumes determined in the planning phase are split in small volumes during the scheduling phase (operational batches) and detailed temporal aspects are determined during the scheduling horizon.

Figure 2 :
Optimization Structure



4. Results

The developed planning model was applied to eight real-world scenarios (S1 to S8) of one month on the described pipeline network. Data as production, consumption, and storage limits vary according to the considered scenario. The results are presented in Table 1, where it can be seen that optimal solutions from the MILP planning model were obtained in less than three seconds, for all the observed scenarios. Sparse sets were used to generate the model and, thus, the number of decisions variables (int. var.) could be significantly reduced. The total quantity of moved product (# moved – in volumetric units – vu) indicates demand variations along the observed time period.

Table 1 : Computational results

	S1	S2	S3	S4	S5	S6	S7	S8
Time (s)	2.9	2.221	2.189	2.143	2.196	2.35	2.327	2.239
Gap (%)	0	0	0	0	0	0	0	0
Iterations	272	278	435	717	417	681	408	442
Variables	1303	1256	1247	1348	1356	1357	1232	1335
Int. var.	588	541	539	633	635	631	532	626
Constraints	2106	2057	2051	2310	2354	2528	2056	2339
# moved (10^6 vu)	2.181	2.015	2.278	2.137	1.993	2.197	2.126	2.267

We also compared the MILP obtained results for scenario 3 (S3) with the real planning approach adopted by the company's specialists (historical data). Table 2 summarizes these results. It is important to notice that the MILP indicated solution was, afterwards, analyzed and validated by the company's specialists.

Table 2: Proposed Model *versus* Company's Approach

Operational Characteristic Observed	MILP Model	Company Solution
Flow reversion: (quantity) and label of pipelines	(#3) 3,22,24	(#6) 1,3,21,23,24,30
Capacity violation: (quantity) and volume	-	(#6) 130249vu
Min. storage violations: (quantity) and volume	-	(#8) 179608vu
Moved volume (without flow reversion)	2,034,133vu	2,125,177vu
Volume in surge tank operations	243,901vu	823,028vu

5. Conclusions

Results of Table 2 indicate that the proposed model suggests a small number of flow reversions of pipelines. Also, when analyzing the occurrence of violations on capacity and minimum storage levels it can be seen that, in the company solution, there are, respectively, six and eight violations. The proposed model was able to attain an operational answer with no product degradation and tankage changes, without violating tankage limits. Within the company solution, to use product degradation an tankage changes was mandatory to solve violation issues. In addition, it is possible to notice that the MILP Model suggested a smaller volume of product to be moved, at the same time that attended demand requirements. Finally, surge tank operations were minimized, causing less equipment maneuvers and, thus, reducing the operating cost.

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