# Optimal blending study for the commercial gasoline

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## Abstract

Commercial ecological gasoline is being obtained by blending multiple components. Increasing a refinery's economic performance depends, among other things, on obtaining optimum blending recipes for the available components. To determine the optimum blending recipe, knowing the mathematical blending model for blending properties estimation and a linear optimization algorithm are necessary. As a blending properties estimation model, the authors used a mathematical model which can be found in the literature, validated through own laboratory experiments. Based on the Simplex algorithm developed by Jean-Pierre Moreau, the authors elaborated a software program, program that was used to study different blending recipes. The studied recipes varied from recipes that took into consideration one restrictive blending property, to recipes that took into consideration two restrictive properties and recipes that took into account one restrictive property, but a fixed proportion of bioethanol in the final blending.

**Keywords**: blending, modelling, linear optimization, optimization program.

## 1. Introduction

The commercial ecological gasoline is obtained by blending a number of components, process which is called formulation. The finished product must fulfill some quality standards, set by today's legislation. To fulfill the imposed quality standards, blending the gasoline's components using different blending recipes is necessary (Suciu, 1993). Commercial gasoline is a blending of three types of components: base components (in proportion of about 60%), correction components (about 40%) and additives (less than 1%). The blending recipes for obtaining commercial gasoline are conceived so as the finished product is suitable in terms of quality. An essential condition for a refinery to function is profitability. Because of this reason, the blending recipes must be chosen so as they bring profits to the refinery. The blending recipe that will yield the highest profit is the optimum blending recipe. To determine the optimum blending recipe, the optimization problem has a linear nature, containing an objective financial function, and a restrictions system. In literature, program packages strictly destined to linear programming and which implement the Simplex algorithm are described. Among these, the following are exemplified:

a) ASLO – represents an advanced implementation of the Simplex method, destined to solve general linear problems of large dimensions (Andrei, 2001).
b) C-WHIZ – the Simplex algorithm containing procedures regarding the problem analysis, which is used to solve problems up to 32000 restrictions (Andrei, 2001).
c) LPAKO – is a program package written in C++, which implements the Simplex method to solve the general linear programming problem (Park et al., 1998).

The purposes of this work are:

a) The elaboration of a dedicated optimization tool.

b) The synthesis of blending recipes using different scenarios.
c) The study the optimal blending properties in relation to the blending quantity.

## 2. Optimization problem

The optimization problem is a mathematical application which selects a solution, among many possible solutions, based on the evaluation of the objective function (Pătrăşcioiu, 2005). The objective function has a financial nature, representing the commercial gasoline cost, computed like the sum of the products between the component cost $c_i$ and the utilized quantity, $x_i$

$$F_{ob} = \sum_{i=1}^{nc} c_i x_i \ . \tag{1}$$

The restrictions system has three components: a) the finished product quality, estimated by a mathematical component blending model; b) components quantities; c) variables non-negativity restrictions (Pătrăşcioiu, Nicolae, 2012).

*2.1. Property Estimation Model*

To estimate the gasoline properties, obtained by blending its components, a linear model, existent in the literature, was utilized (Bărbatu et al., 1970). The model taken into account was validated by Doicin (Doicin, 2014). The model contains mathematical relations for the estimation of the following properties: density, Research octane number, Motor octane number, benzene content, vapor pressure, olefin hydrocarbons content, aromatic hydrocarbons content and oxygen content.

*2.2. Quality and quantity restrictions*

The quality restrictions are derived from the EN228 standard and they refer to the commercial gasoline properties, obtained by its component blending. For the studied problem, the quality restrictions have the form presented in table 1.

Table 1 Gasoline quality restrictions

| Restriction | UM | Restriction Type | Restriction Value |
|---|---|---|---|
| Blending density | $g/cm^3$ | max | 0.775 |
| Research octane number | - | min | 95 |
| Motor octane number | - | min | 85 |
| Final boiling point | °C | max | 210 |
| Aromatic hydrocarbons content | %volume | max | 35 |
| Olefin hydrocarbons content | %volume | max | 18 |
| Oxygen content | %volume | max | 2.7 |
| Vapor pressure | kPa | max | 90 |
| Benzene content | %volume | max | 1 |

The quantity restrictions refer to the total obtained quantity of the gasoline, $M$, and the available quantities of each component. $D_i, i = 1,\ldots,nc$ .

The two restriction types have the following expressions:

$$M = \sum_{i=1}^{nc} x_i \tag{2}$$

$$x_i \le D_i, \quad i = 1,\ldots,nc \tag{3}$$

*2.3. Non-negativity restrictions*

To solve the optimization problem, the Simplex algorithm uses non-negativity restrictions of the $x_i$ variables:

$$x_i \ge 0, \quad i = 1,\ldots,nc \tag{4}$$

## 3. Optimization program

To study the optimum blending recipes, the authors have developed a dedicated software program that allows the interactive study of the blending recipes. The authors have used the Simplex program developed by Jean-Pierre Moreau (Moreau, 2009). The program developed by the authors was written using the Embarcadero Delphi XE3 integrated development environment and it has the following characteristics:

a) A maximum of 9 properties for the determination of the optimum blending recipe can be used;
b) The possibility of selection, from the input data, of both the blending components and the properties that will be taken into account to determine the optimum blending recipe;
c) The possibility of modifying the total quantity of commercial gasoline that can be obtained.

The main window of the program is presented in figure 1. The program determines the optimum blending recipe of the commercial gasoline, being able to be used as a study tool, by modifying the following variables:

- The property or properties that form the restrictions system for the determination of the optimum recipe;
- The total quantity of the finished product that must be obtained;
- The fixed bioethanol quantity (between 0 and 5% volume).

## 4. Optimum blending recipe synthesis

The optimum blending recipes were studied using the following variants:

a) Recipes that take into consideration one restrictive property;
b) Recipes that take into consideration two restrictive properties;
c) Recipes that take into consideration one restrictive property with an imposed bioethanol proportion in the final blending.

*4.1. Recipes that take into consideration one restrictive property*

The objectives followed by this study are the following:

- Dependence of the restrictive property's value of the optimum blending with the total blending quantity that must be obtained;
- The components' distribution with the total blending quantity.

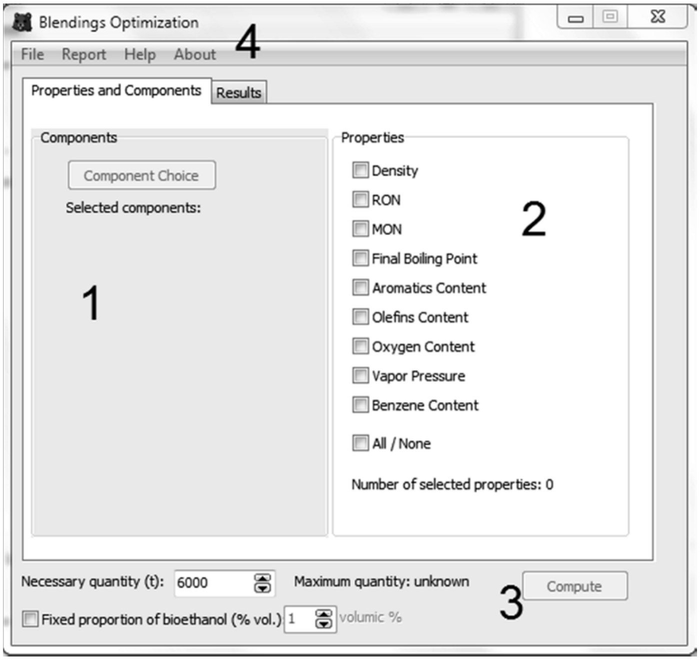


Figure 1:The main window of the optimum blending recipe determining program: 1 –component selection area; 2 –restrictions selection area; 3 –total quantity of gasoline selection zone; 4 – auxiliary menus.

The optimum recipes based on one restriction, from the 9 restrictions present in table 1, were determined. For every restriction taken into consideration, the optimum blending recipes for a total quantity of commercial gasoline varying between 4000 and 9000 t were determined. To exemplify, in figure 2 is presented the variation of the commercial gasoline density with the total quantity of gasoline that must be obtained.

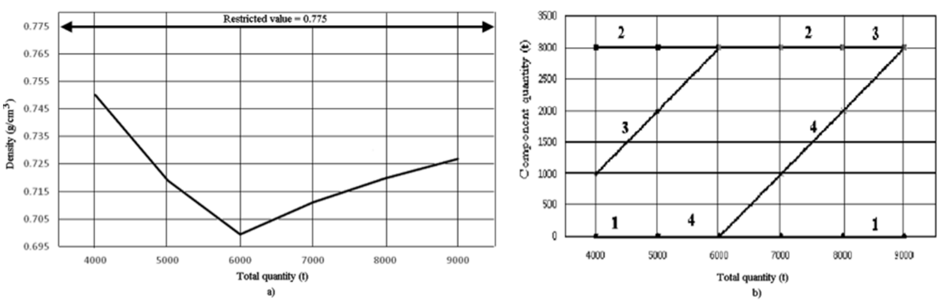


Figure 2 a) commercial gasoline density; b) commercial gasoline composition: 1 – FCC gasoline; 2 – catalytic reforming gasoline; 3 – $iC_5$ fraction; 4 – bioethanol.

The gasoline density obtained using the optimum recipe is under 0.775 (table 1) for the entire variation scope of the total quantity of gasoline. Figure 2b exemplifies the way in which the four components of the commercial gasoline are being used, regarding the total quantity. In the presented case, the components are used, successively: catalytic reforming gasoline (all quantity), $iC_5$ fraction (increasing quantity from 1000 to 3000 t);

bioethanol (increasing quantity from 0 to 3000 t). Because of its high density, the FCC component is not used in the optimum recipe.

*4.2. Recipes that take into consideration two restrictive properties*

The optimization program allowed the study of the dependence of the values of two restrictive properties of the optimum blending with the total blending quantity. In figure 3 the results regarding the density and Motor octane number behavior with the total quantity of gasoline are presented. The blending density constantly increases with the total increase of the quantity of commercial gasoline, this being caused by using a larger increasingly quantities of catalytic reforming gasoline and bioethanol, the components with the highest densities (figure 3a).Meanwhile, the Motor octane number decreases because of using catalytic reforming gasoline, component with lower MON(figure 3-b). From a numerical standpoint, both properties are within the admissible limits. Figure 3-csynthesizes the way in which the optimization program uses successively the four components, along with their quantities.

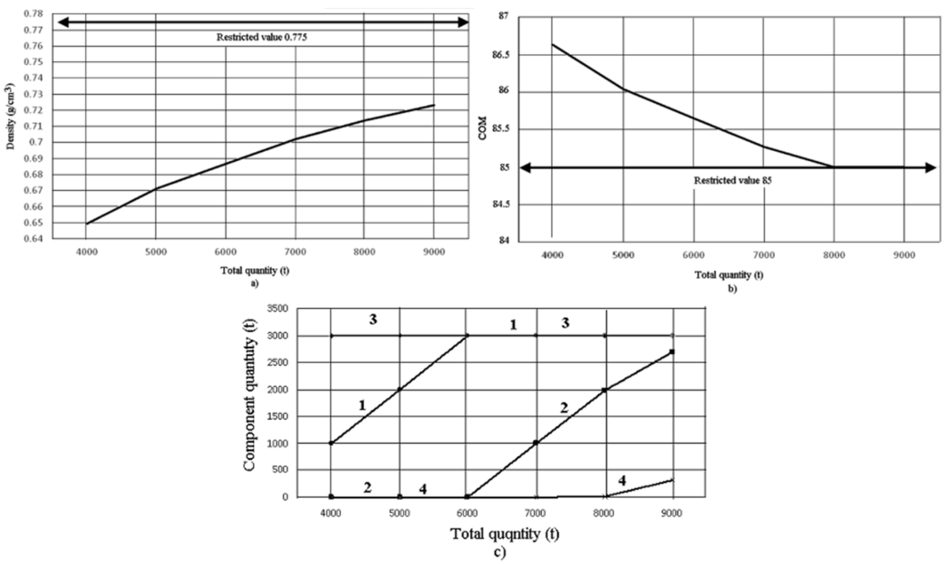


Figure 3 a) commercial gasoline density; b) Motor octane number c) commercial gasoline composition: 1 – FCC gasoline; 2 – catalytic reforming gasoline; 3 – iC5 fraction; 4 – bioethanol.

*4.3. Recipes which have one imposed bioethanol proportion and one restrictive property taken into consideration*

Because of the EN228 standard, the mandatory use of a fixed quantity of bioethanol in the commercial gasoline is necessary. The study of the influence of the bioethanol concentration on the commercial gasoline properties can be made using the same optimization problem. To exemplify, in figure 4 the variation of the gasoline COM with both the total quantity of gasoline and the imposed bioethanol concentration in the commercial gasoline is presented. The bioethanol concentration has varied in steps, between 0 and 5 % volume. The figures 4b and 4c present the variation of the gasoline components both the total quantity of gasoline and the imposed bioethanol concentration.

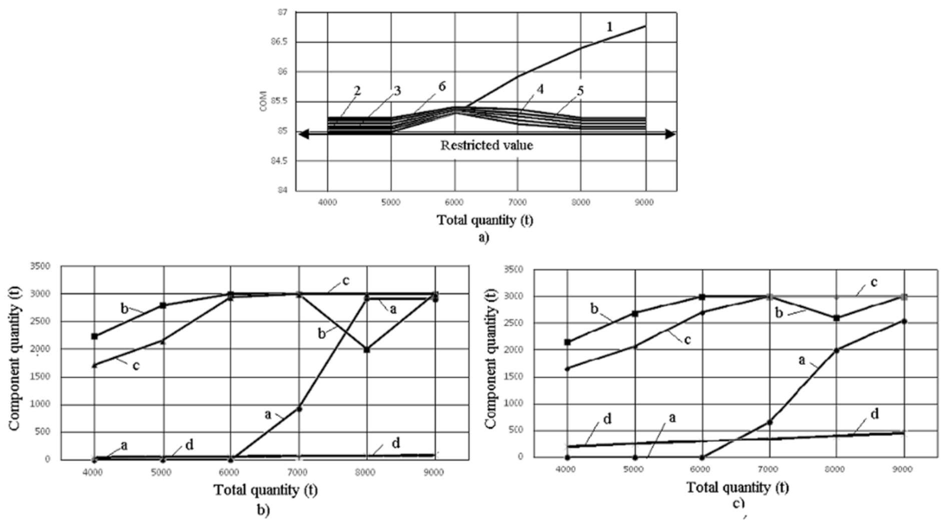


Figure 4 Optimum recipe corresponding to the bleedings with imposed bioethanol quantities: a) COM variation (1 – 0%; 2 – 1%; 3 – 2%; 4 – 3%; 5 – 4%; 6 – 5% bioethanol); b) Component quantitiesfor 1% bioethanol; c) Component quantities for 5% bioethanol (a – FCC gasoline; b – RC gasoline; c – iC5 fraction; d – bioethanol).

## 5. Conclusions

To study the process of obtaining commercial gasoline by optimal blending of different components, the authors have developed: a mathematical model for the estimation of the gasoline properties and an optimization software program to calculate the optimum blending. Using their own software tool, the authors studied the variation of the optimum recipe with the optimal blending quantity. A special attention has been given to study the influence of the bioethanol quantity on the optimum blending properties. The obtained results have confirmed the authors' software potential and this program can be used to quickly verify the optimum blending recipes.

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