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Decisions Optimization Related to the Production Within Refining and Petrochemical Industry

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ABSTRACT
The paper underlines the use of quantitative analyses and mathematical models to optimize the decision within companies from oil and gas industry. It will be presented a case study from a refinery that use RPMS (Refinery and Petrochemical Modeling System) software for optimizing LPG blends.

Key Words: *mathematical models, optimal solution, computer software, RPMS, oil and gas industry*

I. INTRODUCTION

Many organizational problems requiring different managerial decisions have to call quantitative analyses defined by management science. Management science relies on mathematical modeling, a process that transforms some observed phenomena into mathematical expressions. Also, mathematical models translate important business problems into a form suitable for determining an optimal solution by using computer software. Building useful mathematical models is a difficult and complex task and is related with the entire management science process.

This paper is focused on the subjects connected to the petroleum industry. This domain is linked to large projects and has to focus to use a team approach that capitalizes on the talents of the management science analyst as well as those coming from other relevant business disciplines. For instance, the models defining oil industry involve the purchase of crude oil and the manufacture and distribution of various grades of gasoline (upstream, middle-stream and down-stream processes) [1]. In this regard, the team responsible for building the model and evaluating its results could consist of some of the following: chemical engineer, economist, marketing analyst, financial officer, accountant, production manager or transportation specialist [1]. To facilitate and integrate the use of mathematical models in the decision processes, in different and complex industrial activities, are used powerful computer tools.

II. Tools for optimizing the decision

There are more than 20 commercially licensed languages and solvers used for optimization: AMPL, CPLEX, Excel Solver, GAMS, IMSL, MATLAB, MATHCAD, SAS, SCIP etc. For instance, Excel Solver Function is a Microsoft Excel add-in that can be used for evaluation analyzes. The solution will be used to find the optimal (maximum or minimum) value for a formula in a cell, called the objective cell, taking into account constraints or limit values in other cell types with formulas within the worksheet. The solver works with a group of cells, called decision variables or just variable cells, which are used to calculate formulas in objective and constrained cells. The solution adjusts values in decision-makers cells to meet boundaries imposed in constrained cells and produces the desired result in the objective cell [2].

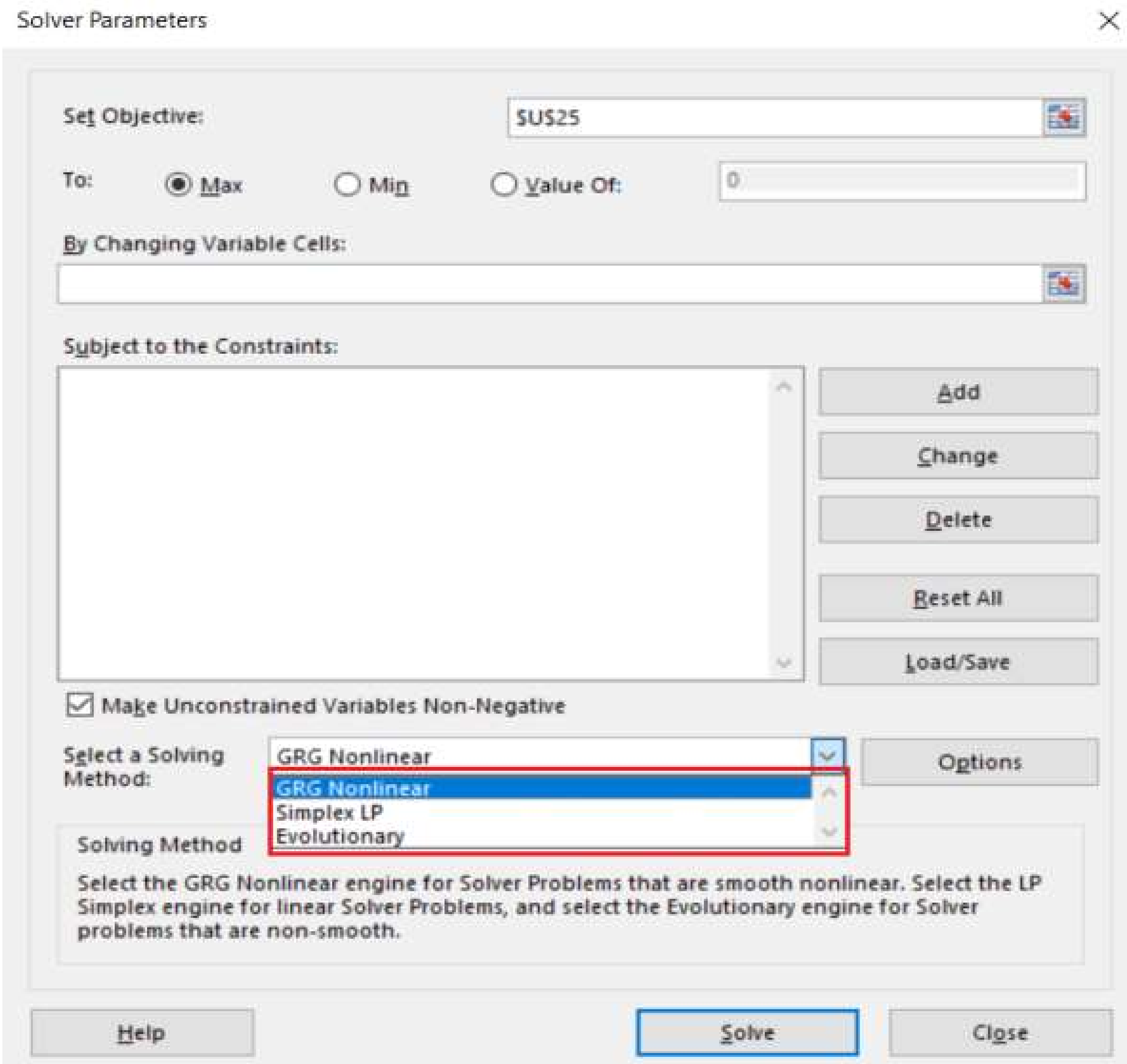

Fig.1 Set parameters in Excel Solver Function (capture from Microsoft Excel 2016)

The solver methods used by Solver are as follows:
1. Generalized Reduced Gradient (GRG) Nonlinear is used for non-linear problems;
2. Linear Programming Simplex is used for linear problems;
3. Evolutionary is used for strong non-linear issues [2].

Another example is represented by FICO Xpress Optimization. The broad portfolio of FICO Xpress Optimization, in terms of optimization options, allows users to build, place and use optimization solutions that meet the requirements. The standard package includes performance solvers and algorithms, flexible modeling environments, fast application development, comparative scenario study and reporting capabilities and cloud installations. Solving a wide range of issues may be the difference between success and failure in today's market environment. FICO® Xpress Optimization allows companies to solve their most difficult problems faster. Xpress Optimization consists of four components:
1. FICO Xpress Insight enables companies to quickly implement optimization models as powerful applications. This allows companies and other users to work with patterns in easy-to-understand terms;
2. FICO Xpress Executor provides independent support for execution optimization services, enabling companies to deploy and run optimization models quickly and easily;
3. FICO Xpress Solver offers the widest range of industry-leading optimization algorithms and technologies to solve linear, mixed and nonlinear numerical problems;
4. FICO Xpress Workbench is an integrated development environment for developing optimization models, services and solutions.

FICO® Xpress Workbench supports and is used with all other FICO Xpress Optimization components [3].

III. Case study regarding the Implementation of RMPS software for optimizing LPG blends

The RPMS software is used for strategic (long-term), medium and current (short term) planning. The recursive linear sequential programming (LP) recursive method is used to search for the solution of optimized production planning problems in RPMS systems [4]. To make the decision known to other organizational structures involved in the production process, economic and logistic analysis, RPMS generates a series of .xls (EXCEL) reports. In order to control the fulfillment of the production plan at least once a week, a meeting will be held with the staff involved in production and delivery management.

The demand for liquefied petroleum gas (LPG) is strongly influenced by the market price of gasoline (the LPG car being the alternative to gasoline for internal combustion engines adapted to the use of LPG) and has a pronounced seasonal character, so in the summer period the demand for LPG increases and decreases during the winter period[5]. The refinery produces 3 types of liquefied petroleum gas (LPG): automotive LPG, LPG type 3 and propylene, based on 4 components: propane, propylene, propane- butane and butane. The properties of the LPG components and their specifications are presented in Tables I and II [6].

TABLE I LPG components and properties

Flow	Production, t	Properties %gr					
		C2, %gr	*C3, %gr*	*C4, %gr*	*C5, %gr*	*Total, %gr*	*C3´, %gr*
Propane	3000	2%	96%	2%	0%	100%	4%
Propylene	4000	1%	97%	2%	0%	100%	96%
Propane-butane	800	1%	40%	58%	1%	100%	0%
Butane	12200	0%	3%	95%	2%	100%	2%
TOTAL	20000						

TABLE II Specifications for LPG for cars, LPG type 3 and propylene

Component	LPG for cars		LPG type 3		Propylene	
	min %gr	*max %gr*	*min %gr*	*max %gr*	*min %gr*	*max %gr*
C2		1%		1%		
C3	36%			35%		
C4			60%			
C5		2%		3%		
C3’		12%		35%	95%	

Depending on the market demand and the season, the price of liquefied petroleum gas may vary. In the absence of logistical and production limitations, the refinery will maximize production of one of three types of LPG products at the expense of other types to maximize the profit.

In the following, it will be analyzed situations in which the price of one of the types of LPG products changes from one another, thus influencing the decision to add propylene to the LPG auto in order to optimize LPG mixtures. Changing the price of one of the practical components will result in two mixes of the three LPG products:

1. The content of propylene in the LPG for cars will be minimal;
2. The propylene content in the automotive LPG will be maximum (max 12% according to the specification in table II).

Case 1 assumes that the sale of propylene as a separate product without additive in the LPG for cars will result in a maximum profit. In tables III to V, are presented the simulation results in the RPMS of Case 1, starting from the data in tables I and II.

TABLE III Production of LPG for cars production (case 1)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	3000	2%	96%	2%	0%	4%
Propylene	0	1%	97%	2%	0%	96%
Propane-butane	800	1%	40%	58%	1%	0%
Butane	5552	0%	3%	95%	2%	2%
Total, t	9352	68	3367	5798	119	231
Total, %gr		0,73%	36%	62%	1,27%	2,47%

TABLE IV Production of LPG type 3 (case 1)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	0	2%	96%	2%	0%	4%
Propylene	0	1%	97%	2%	0%	96%
Propane-butane	0	1%	40%	58%	1%	0%
Butane	6648	0%	3%	95%	2%	2%
Total, t	6648	0	199	6316	133	133
Total, %gr		0,00%	3%	95%	2%	2%

TABLE V Production of propylene (case 1)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	0	2%	96%	2%	0%	4%
Propylene	4000	1%	97%	2%	0%	96%
Propane-butane	0	1%	40%	58%	1%	0%
Butane	0	0%	3%	95%	2%	2%
Total, t	4000	40	3880	80	0	3840
Total, %gr		1,00%	97%	2%	0%	96%

Case 2 assumes that the addition of propylene in the LPG for cars will reduce the amount of LPG type 3 and propylene put up for sale and increase LPG production and get a maximum profit. In tables VI to VIII, are presented the simulation results in the RPMS of Case 1, starting from the data in tables I and II.

TABLE VI Production of LPG for cars production (case 2)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	3000	2%	96%	2%	0%	4%
Propylene	1360	1%	97%	2%	0%	96%
Propane-butane	800	1%	40%	58%	1%	0%
Butane	8065	0%	3%	95%	2%	2%
Total, t	13225	82	4761	8213	169	1587
Total, %gr		0,62%	36%	62,10%	1,28%	12%

TABLE VII Production of LPG type 3 (case 2)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	0	2%	96%	2%	0%	4%
Propylene	0	1%	97%	2%	0%	96%
Propane-butane	0	1%	40%	58%	1%	0%
Butane	4135	0%	3%	95%	2%	2%
Total, t	4135	0	124	3928	83	83
Total, %gr		0%	3%	95%	2%	2%

TABLE VIII Production of propylene (case 2)

Flow	Consumption, t	Properties, %gr				
		C2	*C3*	*C4*	*C5*	*C3'*
Propane	0	2%	96%	2%	0%	4%
Propylene	2640	1%	97%	2%	0%	96%
Propane-butane	0	1%	40%	58%	1%	0%
Butane	0	0%	3%	95%	2%	2%
Total, t	2640	26	2561	53	0	2534
Total, %gr		1%	97%	2%	0%	96%

We can see how the production of LPG assortments changes in both cases. Therefore, in case 2 were 3874 tons more LPG for cars, 2514 tons less LPG type 3 and 1360 tons less propylene. This difference in production of LPG products will underpin the economic analysis of the influence of LPG prices on the propylene addition decision in the automotive LPG (tables IX-XI and figures 2-4). The standard price of LPG for cars, LPG type 3 and propylene are $ 420 / t, $ 320 / t and $ 600 / t, respectively.

TABLE IX Influence of price change for propylene on the decision to add propylene to LPG for cars

Propylene price,$/t	min C3', 10^3 $	max C3', 10^3 $	+/-, 10^3 $
585	8395	8422	27
590	8415	8435	20
595	8435	8449	13
600	8455	8462	7
601	8459	8464	5
602	8463	8467	4
603	8467	8470	3
604	8471	8472	1
605	8475	8475	0
606	8479	8478	-2
607	8483	8480	-3
608	8487	8483	-4
609	8491	8486	-6
610	8495	8488	-7
615	8515	8501	-14
620	8535	8515	-21

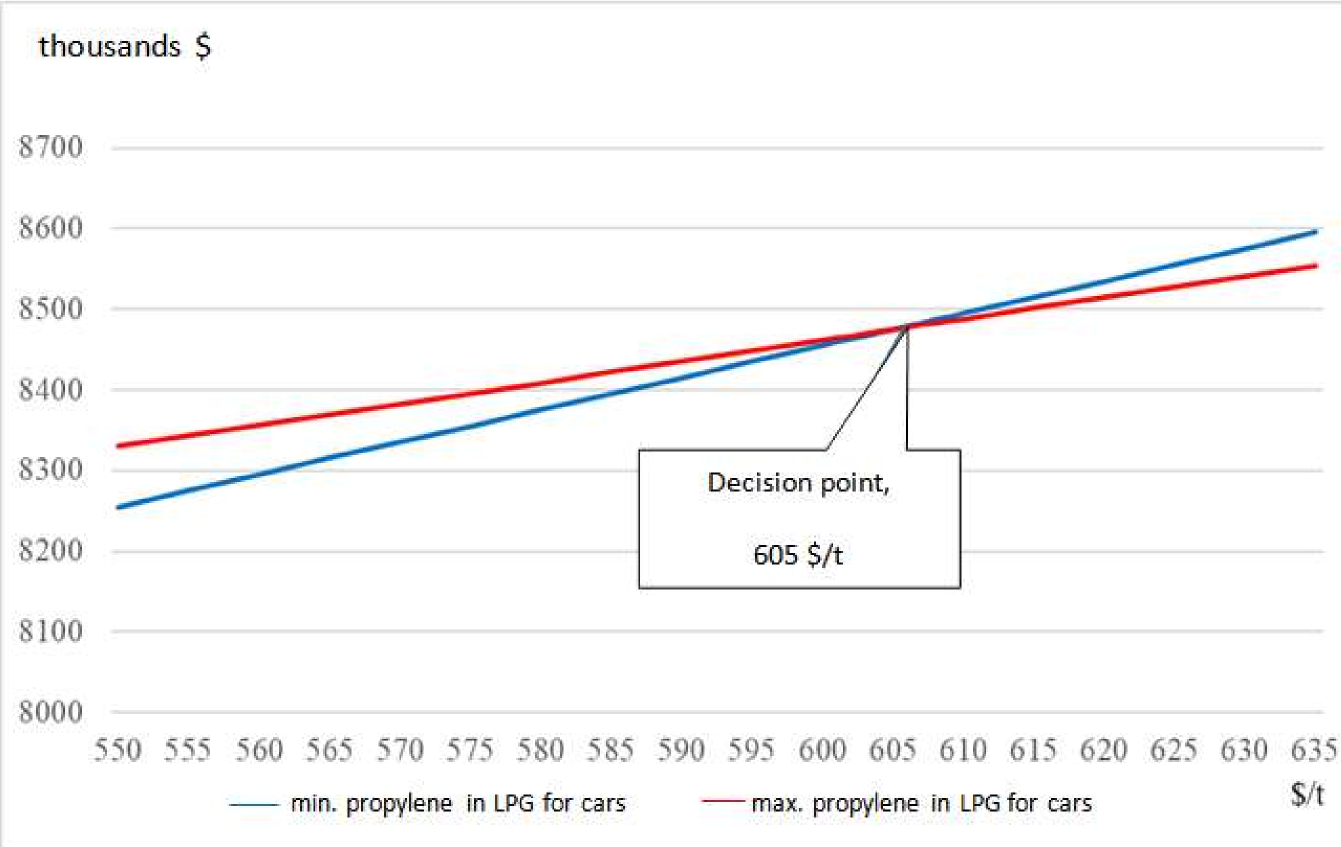

Fig.2 Influence of price change for propylene on the decision to add propylene to LPG for cars

By analyzing table IX and fig.2 it shows that in the case of a propylene price below 605 $ / t, the optimal decision will be to maximize the addition of propylene in the LPG for cars for maximum profit. Above 605 $ / t it is recommended to minimize propylene in the LPG for cars.

TABLE X Influence of price change for LPG type 3 on the decision to add propylene to LPG for cars

Propylene price,$/t	min C3', 10^3 $	max C3', 10^3 $	+/-, 10^3 $
310	8389	8420	32
315	8422	8441	19
320	8455	8462	7
321	8462	8466	4
322	8468	8470	2
323	8475	8474	-1
324	8482	8478	-3
325	8488	8482	-6
330	8522	8503	-19
335	8555	8524	-31

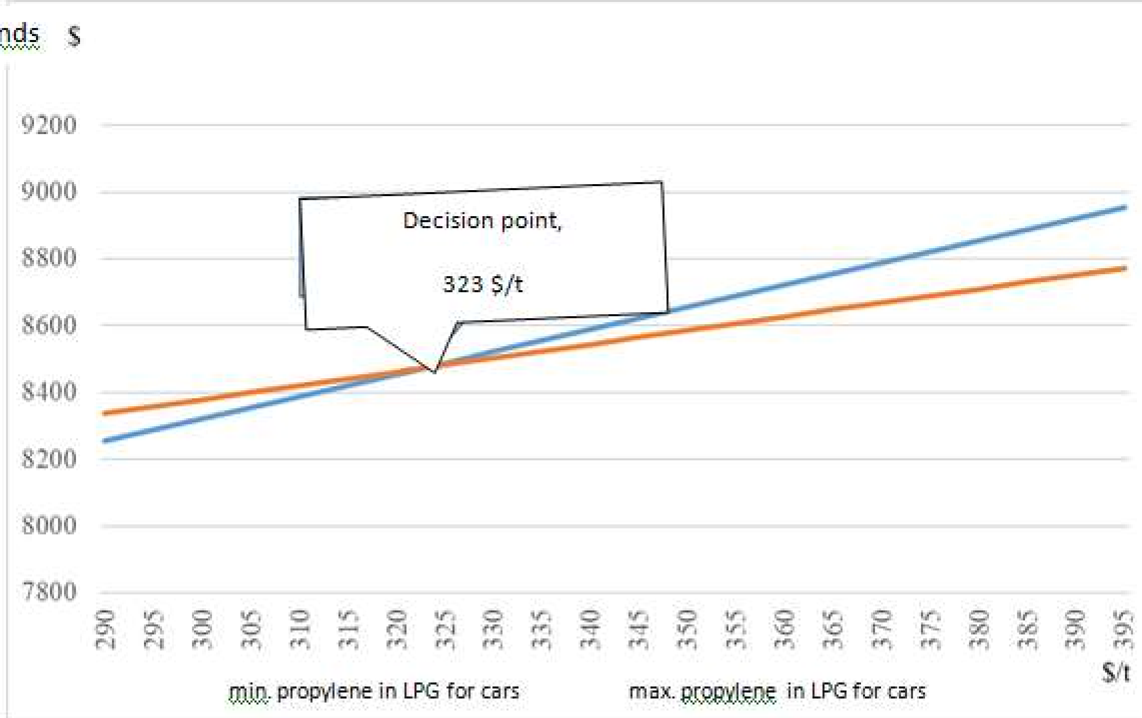

Fig.3 Influence of price change for LPG type 3 on the decision to add propylene to LPG for cars

Analyzing table X and fig. 3, it follows that in the case of a price of LPG type 3 below 323 $ / t, the optimal decision will be to maximize the addition of propylene in the LPG for cars to maximize the profit.

TABLE XI Influence of price change for LPG for cars on the decision to add propylene to LPG for cars

Propylene price,$/t	min C3', 10^3 $	max C3', 10^3 $	+/-, 10^3 $
405	8315	8263	-52
410	8362	8329	-32
415	8408	8396	-13
416	8418	8409	-9
417	8427	8422	-5
418	8436	8435	-1
419	8446	8449	3
420	8455	8462	7
425	8502	8528	26
430	8549	8594	45

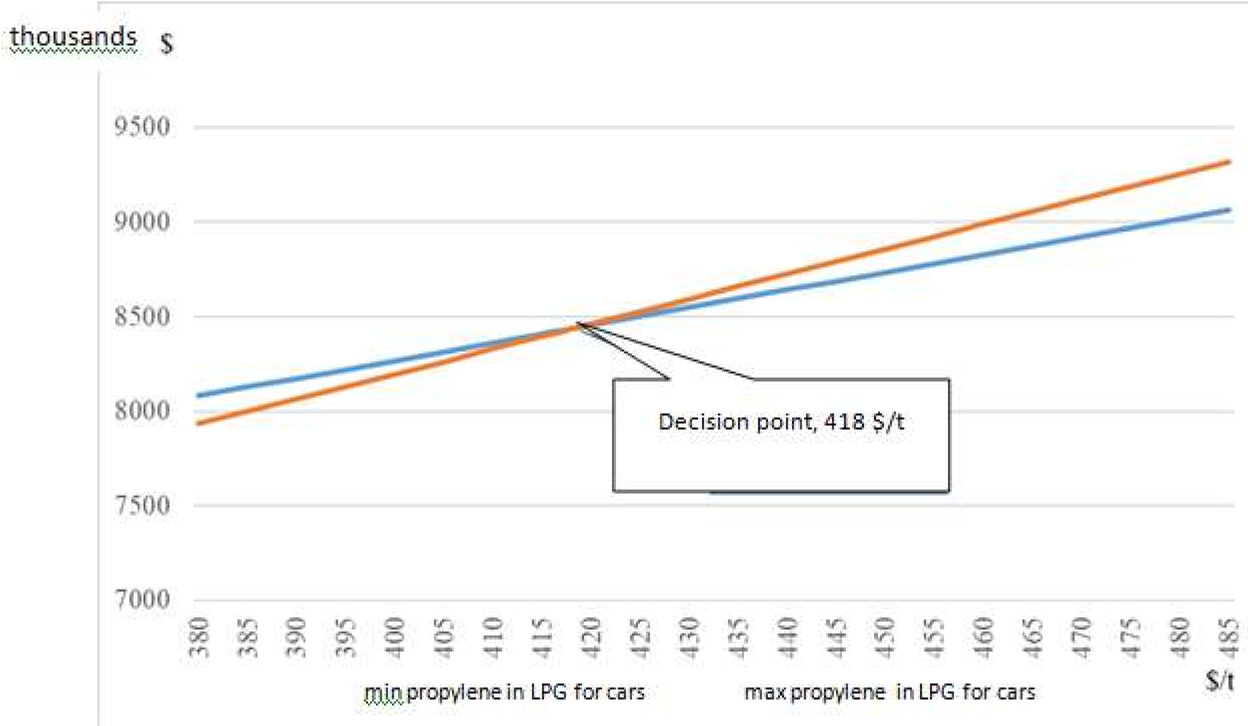

Fig.4 Influence of price change for LPG for cars on the decision to add propylene to LPG for cars

Analyzing table XI and fig. 4, it follows that in the case of a LPG price lower than $ 418 / t, the optimal decision will be to minimize the addition of propylene in the LPG for cars for maximum profit. Above 418 $ / t it is recommended to maximize propylene in the LPG for cars.

IV. Conclusions

In order to find out the optimal solution in a production matter, regarding the refining and petrochemical industry, there is useful to identify proper software that could assist the manager. Therefore this paper has exemplified the capabilities of RPMS (Refinery and Petrochemical Modeling System) software. The case study refers to optimizing LPG blends within a refinery. It was determined, taking in account different scenarios, the decision points in order to maximize the profit.

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