MULTI PERIOD BLENDING OPTIMISATION

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ABSTRACT

The Refinery Blending Manager's main objective is to fulfil the production program coping with inventories, intermediates' quality and logistic constraints. Off-spec production compromises this objective and quality give-away may arise from uncertainty to achieve on-spec product with available intermediates.

Even though the optimal recipe depends also on current market scenario and on the intermediates shadow values calculated by LPs, usually the Blending Manager has neither the means nor the time to take decisions considering these aspects.

OTTMIX – the Prometheus application dedicated to Blending Optimisation – is designed to provide the Blending Manager with a reliable tool calculating optimal recipes according to current inventory, market scenario, logistic constraints and production schedule: the application manages autonomously the operational research issues (matrix generation, optimisation, solution reporting) thus no additional skills are requested to the user. The increasing confidence of the Blending Manager into application's predictions results into the effective progressive reduction of quality give away and laboratory work.

Describing the deployment of a Multi Period Blending Program for a complex conversion refinery (based on a real case), the author analyses the impact of alternative market scenarios and inventory constraints on the optimal recipe and estimates the resulting economical income.

BACKGROUND

Finished products blending constitutes one of the most delicate phases of the whole oil refining process: often these operations are not considered with right attention by refiners even if the poor optimisation of this operation can potentially frustrate good part of the efforts effected for improving the refining process.

Blending Optimisation means the maximisation of the economical return obtainable by product Sales – or more explicitly – the maximisation of high-value products yields; this usually (but not necessarily) coincides with the minimisation of quality give away.

As a "thumb rule" blending margins can be improved maximising the use of low-value intermediates for the production of high-value products; this is generally true but cannot abstract from an holistic approach: intermediate components management must account for all the grades to be produced and should be driven by the results of planning and scheduling applications. Moreover it is not easy to define the relative values of blend components, which depend on the processing economics and may change over time.

Refinery blending procedures can be considered in two major categories[1]:

- Batch Blending, undertaken with or without blenders, using one or several tanks for the production of a commercial product,
- In-line Blenders, using on-line analysers at the output of the blender, so that an on-specification product is delivered either into the finished product tank or dispatched directly to the customer.

Modern plants privilege In-line blenders because of the higher performances provided:

- Lower time needed for product manufacture: batch blending involves constraints due to homogenisation, quality control and laboratory tests that are overcome thanks to the availability of online analysers. This permits to reduce stock levels and maintenance costs related to off-site facilities (lower amount of stock volume required per ton of product delivered).
- Better quality monitoring: sampling may be problematic in case of batch blending since sample reliability could be affected by poor of homogenisation. In case of in-line blending this problem is limited to the reliability of the analyser and is not affected by homogenisation.
- Management of complex formulations: the increasing number of commercial specifications to be controlled and of components available (resulting from the increased processing complexity) complicates the blending problem: in-line blending formulations are calculated by Multivariable on-line controllers (applying LP Methods and controlling simultaneously more quality specifications) while these supports are rarely used in case of batch blending.

Notwithstanding all these advantages the refineries in the world equipped with in-line blenders are nearly the 20 percent[1]: this is mainly due to the high cost of investment involved:

in-line blending requires the implementation of off-sites automation that means the set-up of a Tank Management System (providing data for off-sites operator management), of an Automatic Transfer Management System (needing an adequate instrumentation and permitting the automation of transfers) and of a Blend Management system (comparing the availability of component tanks with scheduling requirements and automating in-line product formulation).

Especially in case of existing blending facilities the elevate number of additional equipment and instrumentation required to adequate tank farms to in-line blending discourages Refiners from investing and Batch Blending approach continues to be applied.

The aim of this work is to improve the profitability of Batch Blending with a software application supporting the planning of blending operation and providing the Blending Operator (who is charged to decide when and how to prepare product tanks) with the same technologies exploited by multivariable controllers.

The Batch Blending Operator, who does not dispose of on-line analysers providing real time data, is generally induced to take safety margins to be sure that the tank will be on-specification with no need of further quality corrections.

As a matter of fact one of the main advantages of in-line blending is the reduction of quality give-away: in case of not automated batch blending, a positive contribution in this direction can be obtained providing the Operator with a system predicting in a reliable way the quality of the resulting mixture; this progressively <u>improves his confidence in the results of the operation permitting him to reduce safety margins</u>.

To provide concrete results the system must be able to model in detail the Blending Operations (with all the necessary complexity degrees), being at the same time of simple usage (with an interface oriented to Operator mentality and able to autonomously manage the techniques applied to solve the problem).

As an example, the weekly schedule of gasoline blending operation in the internal depot of a complex conversion Refinery is handled with the help of OTTMIX, the Prometheus Solution dedicated to Finished Products Blending. Quality and availability of blending components, tank bottoms, product specifications, formulations, logistic constraints and delivery schedule are used to build automatically a Multi Period LP/MIP model aimed to find the most profitable way to satisfy problem constraints.

[1] Refinery Operation and Management, J.P. Favennec, Editions Technip, 2001

PROBLEM DEFINITION

In the Refinery whose case is modelled as example, the Blending Operator Prepares Finished Products in the tanks of the internal Depot; when a tank is ready (full and on-specification), its content is transferred to the external Depot where it is made available for tank truck or tank wagon loading facilities. Usually the internal depot's tanks are filled during the day while transfers to external depot are made overnight.

Tank content quality is monitored with laboratory analysis that are time expensive and affect the whole tank preparation process: one of the expected goals is reduce the number of tests required for each tank.

Starting from the week shipping schedule, considering intermediates availability and quality, the Blending Operator decides which tank to prepare, how and when. While taking these decisions he ought to:

- *Minimise quality give away*: not only formulate a product on-specification but also to use at best available components maximising the economical return (the value of high quality intermediates is typically higher of poor quality ones).
- *Manage intermediates*: consider current and expected availability of each blending component in order to avoid unforeseen shortage or excess.
- *Manage blending facilities*: schedule each tank preparation coping with logistic constraints and trying to optimise each tank use factor.

The problem that is modelled in this example is the preparation of Gasoline products in the tanks of the Internal Depot: Table 1 reports the commercial specifications of the four grades of Gasoline produced and Table 2 the geometric data of the eight tanks destined to their preparation.

The components used for the gasoline blending are listed in Table 3: quantity and quality data of the intermediate products produced by the Refinery depends on Plants' operative conditions and are updated retrieving data from refinery database.

Besides Butane and MTBE, high octane components are produced by Isomerisation and Reforming Units: neither Cracking Naphtha nor Alkylate Cuts are available for gasoline Blending.

SPECIFICATION	UNIT	HEAVY NAPHTHA		LIGHT NAPHTHA		UNLEADED		UNLEADED PLUS	
		Min	Max	Min	Max	Min	Max	Min	Max
Antiknock Additives		Clear		Clear		Clear		Clear	
Density	kg/dm3	0.660	0.730	0.630	0.660	0.720	0.775	0.720	0.775
Sulphur	ppm		500		300		150		150
Paraffines	%v	65.0		87.0					
Aromatics	%v		12.0		4.0		37.8		40.0
Benzene	%v						0.9		0.9
Octane Number Motor	_					85.2		87.2	
Octane Number Research	_					95.2		98.2	
Reid Vapour Pressure	bar		0.840			0.500	0.800	0.600	0.900
Recovered@70℃	%v						48		50
Recovered@100℃	%v						71		71
Recovered@125℃	%v	50		95					
Recovered@150℃	%v					75		75	
Recovered@165	%v	95							
Recovered@180℃	%v							85	
Naphthenes + Aromatics	%v				13				
Vapour Lock Index	_						1050		1150

Table 1 – Gasoline Products Grades

NAME	PRODUCT	MINIMUM VOLUME [m3]	MAXIMUM VOLUME [m3]
TK002	Unleaded	1308	6594
TK004	Unleaded	1048	6309
TK005	Unleaded	2001	8667
TK006	Unleaded	2037	8876
TK011	Unleaded Plus	884	5109
TK022	Heavy Naphtha	600	4789
TK023	Light Naphtha	212	982
TK027	Heavy Naphtha	234	2007

Table 2 – Gasoline Products Tanks

NAME	DESCRIPTION
Butane	Butanes mixture from LPG Treatment Unit
MTBE	Imported Methyl Tert-Butyl Ether
Isomerate	Naphtha from C5/C6 Isomerisation Unit with Recycle of Hexanes
SR L.Naphtha	Straight Run Hydrotreated Light Naphtha from Splitter Unit
SR M.Naphtha	Straight Run Hydrotreated Mid Naphtha (Benzene precursors cut) from Splitter Unit
SR H.Naphtha	Straight Run Hydrotreated Heavy Naphtha from Splitter Unit
DH Bottom	Bottom of Isomerisation Unit DeIsoHexaniser
Reformate + IC5	Naphtha from Reforming Unit mixed in plant with Iso-Pentane produced from Light Naphtha DeIsoPentaniser

Table 3 – Intermediate Components

SYSTEM DESCRIPTION

The problem has been handled using OTTMIX, the Prometheus Linear Programming optimiser dedicated to Refinery Blending operations. Applying LP and MIP techniques, the software calculates the best way to produce LPG, Gasoline, Distillates and Fuel Oils from intermediate refinery stocks, accounting for Market prices, Intermediates stock quality and quantity, Product specifications and Production targets.

If the technological background is the same of LP Planning Applications (and partially of Multivariable Controllers used for in-line Blending Systems), program operating environment has been specialised to handle the Blending Problem, providing functions specifically designed for this aim: one of the founding ideas of Prometheus' Vision consists in promoting the widespread use of Optimisation Models by removing (or reducing) the technological gap that up to now has impeded their application outside of the Planning Department. To operate the Model a mathematical background is not needed, and just a good understanding of the specific operation (Blending in this case) is requested.

The simplicity of use of the model doesn't involve any structural rigidity: the blending operation has been deepened to equip the program with the necessary flexibility to model every different problem. Moreover expert users can directly improve the LP model by adding User Balances, Variables, Coefficients and Constraints.

CHARACTERISATION OF BLENDING COMPONENTS

Covering the entire crude oil boiling range the application manages four types of physical properties, *Generic* (covering most part of the properties useful to model a Blend), *Evaporate* (weight or volume fraction recovered at a given Boiling Temperature for a given distillation test), *Temperature* (Boiling Temperature corresponding to a given recovered fraction for a given distillation test) and *Composite* (automatically calculated with a formula from other property values, for example [RON + MON] / 2).

Program predefined properties are listed in Table 4.

For any category it is possible to define additional *User Defined Properties* with their specific characteristics (Unit, Formats, Mixing Rule, Blending Indices, etc.); Figure 1 shows the application's panel useful to manage Physical Properties.

All the physical property defined in the Model are available for intermediate components characterisation and can be used to define commercial specifications once that a Mixing Rule has been provided.

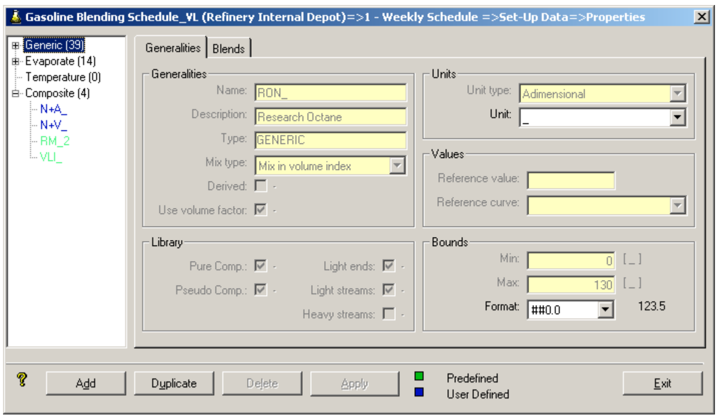


Figure 1 – Property Manager Panel

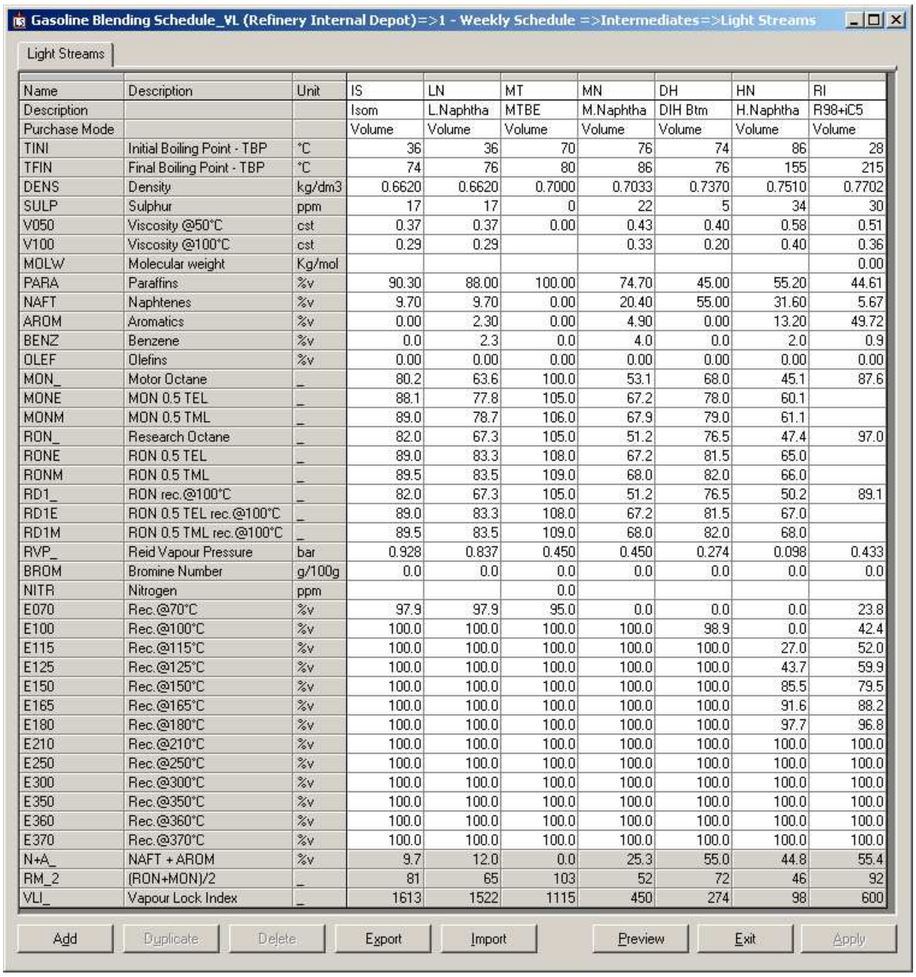
Depending on their boiling range, Blending components can be allocated over three categories:

- *Light Ends*: components that can be characterised from the composition (usually LPG or very light fractions) and whose property values are directly calculated by the program.
- *Light Streams*: components characterised with properties useful for Gasoline blending.
- *Heavy Streams*: components characterised with properties useful for Mid Distillates and Fuel Oil Blending.

Figure 2 shows the characterisation properties of the Light Streams used in this example: it is necessary to provide all the property values related to the commercial specifications set for the products to be prepared.

In the case of this example the characterisation data calculated by the refinery scheduler have been entered, but they can also be retrieved from Refinery Information System taking advantage of data Import/Export capability.

There is no theoretical limit to the number of components used by the model.



Name	Description	Unit	IS	LN	MT	MN	DH	HN	RI
Description			Isom	L.Naphtha	MTBE	M.Naphtha	DIH Btm	H.Naphtha	R98+iC5
Purchase Mode			Volume	Volume	Volume	Volume	Volume	Volume	Volume
TINI	Initial Boiling Point - TBP	°C	36	36	70	76	74	86	28
TFIN	Final Boiling Point - TBP	°C	74	76	80	86	76	155	215
DENS	Density	kg/dm3	0.6620	0.6620	0.7000	0.7033	0.7370	0.7510	0.7702
SULP	Sulphur	ppm	17	17	0	22	5	34	30
V050	Viscosity @50°C	cst	0.37	0.37	0.00	0.43	0.40	0.58	0.51
V100	Viscosity @100°C	cst	0.29	0.29		0.33	0.20	0.40	0.36
MOLW	Molecular weight	Kg/mol							0.00
PARA	Paraffins	%v	90.30	88.00	100.00	74.70	45.00	55.20	44.61
NAFT	Naphtenes	%v	9.70	9.70	0.00	20.40	55.00	31.60	5.67
AROM	Aromatics	%v	0.00	2.30	0.00	4.90	0.00	13.20	49.72
BENZ	Benzene	%v	0.0	2.3	0.0	4.0	0.0	2.0	0.9
OLEF	Olefins	%v	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MON_	Motor Octane	_	80.2	63.6	100.0	53.1	68.0	45.1	87.6
MONE	MON 0.5 TEL	_	88.1	77.8	105.0	67.2	78.0	60.1	
MONM	MON 0.5 TML	_	89.0	78.7	106.0	67.9	79.0	61.1	
RON_	Research Octane	_	82.0	67.3	105.0	51.2	76.5	47.4	97.0
RONE	RON 0.5 TEL	_	89.0	83.3	108.0	67.2	81.5	65.0	
RONM	RON 0.5 TML	_	89.5	83.5	109.0	68.0	82.0	66.0	
RD1_	RON rec.@100°C	_	82.0	67.3	105.0	51.2	76.5	50.2	89.1
RD1E	RON 0.5 TEL rec.@100°C	_	89.0	83.3	108.0	67.2	81.5	67.0	
RD1M	RON 0.5 TML rec.@100°C	_	89.5	83.5	109.0	68.0	82.0	68.0	
RVP_	Reid Vapour Pressure	bar	0.928	0.837	0.450	0.450	0.274	0.098	0.433
BROM	Bromine Number	g/100g	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NITR	Nitrogen	ppm			0.0				
E070	Rec.@70°C	%v	97.9	97.9	95.0	0.0	0.0	0.0	23.8
E100	Rec.@100°C	%v	100.0	100.0	100.0	100.0	98.9	0.0	42.4
E115	Rec.@115°C	%v	100.0	100.0	100.0	100.0	100.0	27.0	52.0
E125	Rec.@125°C	%v	100.0	100.0	100.0	100.0	100.0	43.7	59.9
E150	Rec.@150°C	%v	100.0	100.0	100.0	100.0	100.0	85.5	79.5
E165	Rec.@165°C	%v	100.0	100.0	100.0	100.0	100.0	91.6	88.2
E180	Rec.@180°C	%v	100.0	100.0	100.0	100.0	100.0	97.7	96.8
E210	Rec.@210°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
E250	Rec.@250°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
E300	Rec.@300°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
E350	Rec.@350°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
E360	Rec.@360°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
E370	Rec.@370°C	%v	100.0	100.0	100.0	100.0	100.0	100.0	100.0
N+A_	NAFT + AROM	%v	9.7	12.0	0.0	25.3	55.0	44.8	55.4
RM_2	(RON+MON)/2	_	81	65	103	52	72	46	92
VLI_	Vapour Lock Index	_	1613	1522	1115	450	274	98	600

Figure 2 – Light Streams Characterisation Data

MODELLING COMMERCIAL SPECIFICATIONS

OTTMIX manages various types of Commercial Specifications depending on the nature of the object to be controlled:

- *Property*: to control the value of product property (for example: Max Density equal to…)
- *Component list*: to control the concentration of a list of pure components contained in the product (for example: Max C2 minus content in LPG products)
- *Additives*: to model the contribution and the costs related to the use of additives (for example: Pour Point Depressants or Cetane Improvers)
- *Antiknock Additives*: to model the behaviour of lead based Antiknock Additives (TEL and TML).

It is possible to associate commercial specifications to each characterisation object defined in the Model (Figure 3).

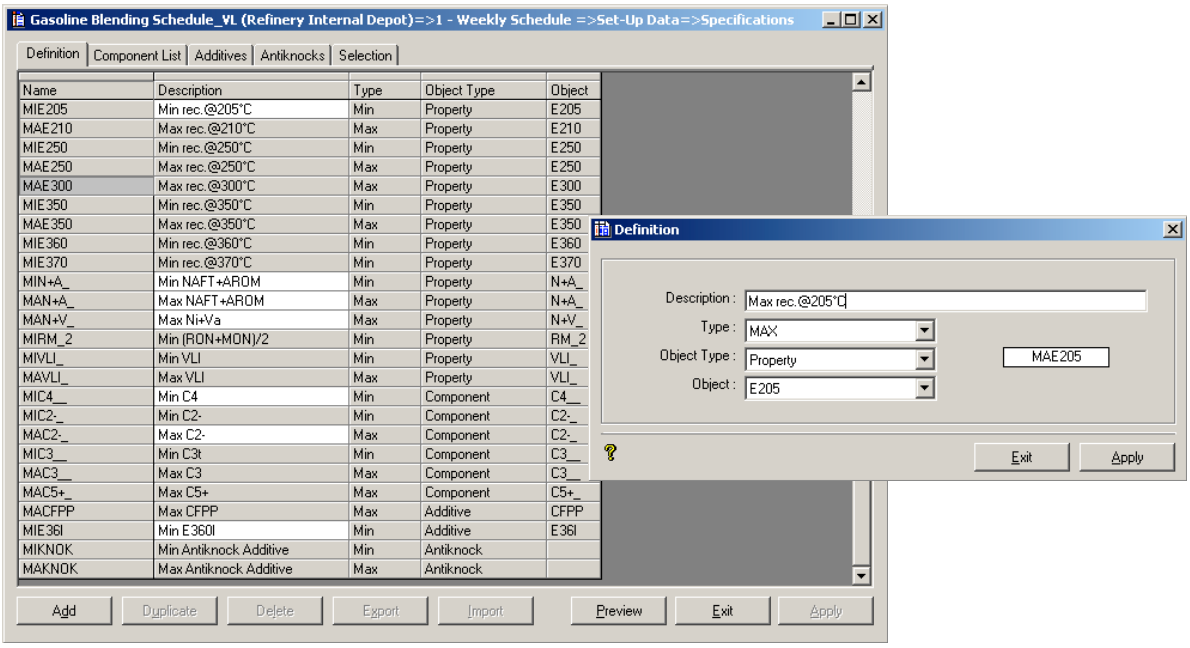


Figure 3 – Commercial Specifications Types and Definition

Commercial specification constraints are set for each Product Tank (Figure 4): this constraints are always mandatory and the application can not suggest formulations with “Out of Specification” products.

Gasoline Blending Schedule_VL (Refinery Internal Depot)=>1 - Weekly Schedule =>Products=>Gasolines

Definition | Composition | Additives | Volume Factors

Name	Description	Unit	E1	E2	F1	G1	G2	G3	G4	H1
Description			H. Naphtha	H. Naphtha	L. Naphtha	Unleaded	Unleaded	Unleaded	Unleaded	Unlead. Plus
Sale Mode			Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume
Dest. Tank			022 - V.Nph	027 - V.Nph	023 - V.Nph	002 - Unl.95	004 - Unl.95	005 - Unl.95	006 - Unl.95	011 - Unl.98
Antiknock			Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
MIKNOK	Min Antiknock Additive	g/lt								
MAKNOK	Max Antiknock Additive	g/lt								
MIDENS	Min Density	kg/dm3	0.6600	0.6600	0.6300	0.7200	0.7200	0.7200	0.7200	0.7200
MADENS	Max Density	kg/dm3	0.7300	0.7300	0.6600	0.7750	0.7750	0.7750	0.7750	0.7750
MASULP	Max Sulphur	ppm	500	500	300	150	150	150	150	150
MIPARA	Min Paraffines	%v	65.00	65.00	87.00					
MAAROM	Max Aromatics	%v	12.00	12.00	4.00	37.80	37.80	37.80	37.80	40.00
MABENZ	Max Benzene	%v				0.9	0.9	0.9	0.9	0.9
MIMON_	Min MON	_				85.2	85.2	85.2	85.2	87.2
MIRON_	Min RON	_				95.2	95.2	95.2	95.2	98.2
MARON_	Max RON	_								
MIRD1_	Min RON rec.@100°C	_								
MIRVP_	Min RVP	bar				0.500	0.500	0.500	0.500	0.600
MARVP_	Max RVP	bar	0.840	0.840		0.800	0.800	0.800	0.800	0.900
MIE070	Min rec.@70°C	%v								
MAE070	Max rec.@70°C	%v				48.0	48.0	48.0	48.0	50.0
MIE100	Min rec.@100°C	%v								
MAE100	Max rec.@100°C	%v				71.0	71.0	71.0	71.0	71.0
MIE115	Min rec.@115°C	%v								
MAE115	Max rec.@115°C	%v								
MIE125	Min rec.@125°C	%v	50.0	50.0	95.0					
MIE150	Min rec.@150°C	%v				75.0	75.0	75.0	75.0	75.0
MIE165	Min rec.@165	%v	95.0	95.0						
MIE180	Min rec.@180°C	%v								85.0
MIN+A_	Min NAFT+AROM	%v								
MAN+A_	Max NAFT+AROM	%v			13.0					
MIRM_2	Min (RON+MON)/2	_								
MIVLI_	Min VLI	_								
MAVLI_	Max VLI	_				1050	1050	1050	1050	1150

Add | Duplicate | Delete | Export | Import | Preview | Exit | Apply

Figure 4 – Product Tank Commercial Specifications

Besides commercial specifications, the Model permits to specify which intermediate components the model can use to prepare each finished product (Figure 5): composition ranges (min/max weight percent content in the finished product) may be also set at this level.

Gasoline Blending Schedule_VL (Refinery Internal Depot)=>1 - Weekly Schedule =>Products=>Gasolines

Definition | Composition | Additives | Volume Factors

Name	Unit	E1	E2	F1	G1	G2	G3	G4	H1
Description		H. Naphtha	H. Naphtha	L. Naphtha	Unleaded	Unleaded	Unleaded	Unleaded	Unlead. Plus
BU	%w	NO	NO	NO	0 - 3	0 - 3	0 - 3	0 - 3	0 - 3
DH	%w	YES	YES	NO	YES	YES	YES	YES	YES
HN	%w	YES	YES	NO	YES	YES	YES	YES	YES
IS	%w	NO	NO	NO	YES	YES	YES	YES	YES
LN	%w	NO	NO	YES	YES	YES	YES	YES	YES
MN	%w	NO	YES	YES	YES	YES	YES	YES	YES
MT	%w	NO	NO	NO	0 - 14	0 - 14	0 - 14	0 - 14	0 - 14
RI	%w	NO	NO	NO	YES	YES	YES	YES	YES

Add | Duplicate | Delete | Export | Import | Preview | Exit | Apply

Figure 5 - Defining Product Composition

<u>Mixing Rules</u>

One of the main issues involved with Blending Operation modelling is the prediction of hydrocarbon mixtures' properties: in some cases for a reliable prediction of mixture's quality, property values must be converted into indexes before being linearly blended on weight or volume basis.

The calculation of properties with linear behaviour is represented by (1), being P_i and Q_i the property value and the quantity (weight or volume) respectively of each blending component and P_m and Q_m the property value and the quantity of the mixture:

(1) $$P_m*Q_m = \Sigma\ (P_i*Q_i)$$

If linearisation indexes are used, the formula becomes (2), being *Idx*() the linearization function applied to the property value:

(2) $$Idx(P_m)*Q_m = \Sigma\ [Idx(P_i)*Q_i]$$

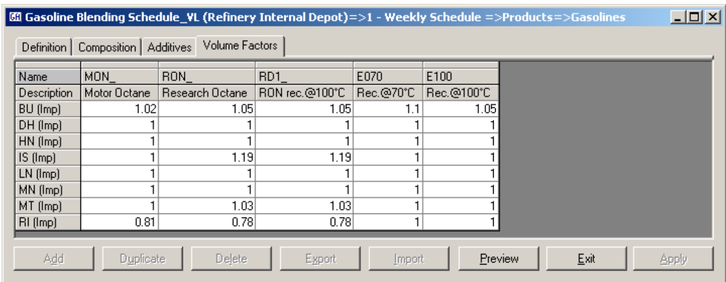
Moreover, to calculate some particular properties (Antiknock, Evaporates), additional parameters (Volume Factors) must be considered in the blending calculation to account for the physical / chemical behaviour of each component. For instance the resulting RON of two mixtures SR Naphtha / Reformate and SR Naphtha / Isomerate is different even if Reformate and Isomerate have the same RON: this behaviour is due to the different chemical structure of the two components. In this last case the calculation formula becomes (3) or (4), being Fi the correction factor associated to each blending component.

(3) $$P_m* \Sigma\ (Q_i*F_i)= \Sigma\ (P_i*Q_i*F_i)$$

(4) $$Idx(P_m)* \Sigma\ Q_i*F_i = \Sigma Idx(P_i)*Q_i*F_i$$

Table 4 details the type of Mixing Rule applied to manage each hydrocarbon predefined property; the system manages also User Proprietary Methods.

Figure 6 shows some Volume Factor Values: a detailed study should be carried out basing on historical data to find the values best fitting the real contribution of each Blending Component.



Name	MON_	RON_	RD1_	E070	E100
Description	Motor Octane	Research Octane	RON rec.@100°C	Rec.@70°C	Rec.@100°C
BU (Imp)	1.02	1.05	1.05	1.1	1.05
DH (Imp)	1	1	1	1	1
HN (Imp)	1	1	1	1	1
IS (Imp)	1	1.19	1.19	1	1
LN (Imp)	1	1	1	1	1
MN (Imp)	1	1	1	1	1
MT (Imp)	1	1.03	1.03	1	1
RI (Imp)	0.81	0.78	0.78	1	1

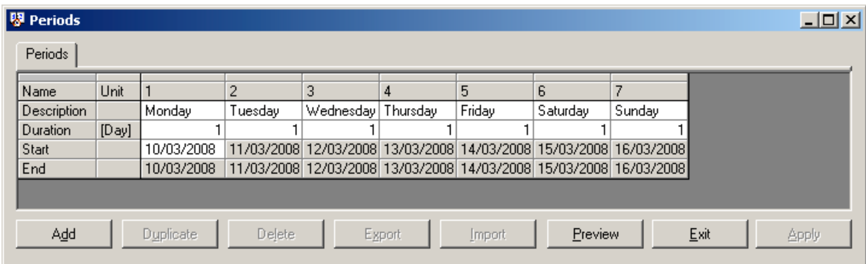
Figure 6 - Volume Factors

PROPERTY	TYPE (1)	MIX RULE (2)	VOL FACT (3)	PROPERTY	TYPE (1)	MIX RULE (2)	VOL FACT (3)
Standard Density	G	LV	NO	Pour Point	G	IV	NO
Sulphur Content	G	LW	NO	Nitrogen Content	G	LW	NO
Kinematic Viscosity@50°C	G	IW	NO	Aniline Point	G	LW	NO
Kinematic Viscosity@100°C	G	IW	NO	Cetane Index	G	LV	NO
Paraffins Content	G	LV	NO	Diesel Index	G	LV	NO
Naphthenes Content	G	LV	NO	Ash Content	G	LW	NO
Aromatics Content	G	LV	NO	Asphaltenes Content	G	LW	NO
Benzene Content	G	LV	NO	Conradson Carbon	G	LW	NO
Olefins Content	G	LV	NO	Nickel Content	G	LW	NO
MON (Motor Octane Number)	G	LV	YES	Vanadium Content	G	LW	NO
MON Tetra Ethyl Lead 0.5 (4)	G	LV	YES	Test D86 Rec@070°C	E	LV	YES
MON Tetra Methyl Lead 0.5 (4)	G	LV	YES	Test D86 Recovered@100°C	E	LV	YES
RON (Research Octane Number)	G	IV	YES	Test D86 Recovered@150°C	E	LV	NO
RON Tetra Ethyl Lead 0.5 (4)	G	IV	YES	Test D86 Recovered@180°C	E	LV	NO
RON Tetra Methyl Lead 0.5 (4)	G	IV	YES	Test D86 Recovered@210°C	E	LV	NO
RON Recovered @ 100°C	G	IV	YES	Test D86 Recovered@250°C	E	LV	NO
RON Rec@100°C TEL0.5 (4)	G	IV	YES	Test D86 Recovered@300°C	E	LV	NO
RON Rec@100°C TML0.5 (4)	G	IV	YES	Test D86 Recovered@350°C	E	LV	NO
Reid Vapour Pressure	G	IV	NO	Test D86 Recovered@360°C	E	LV	NO
Bromine Number	G	LW	NO	Test D86 Recovered@370°C	E	LV	NO
Flash Point	G	IV	NO	(RON + MON) / 2	C	LV	NO
Freezing Point	G	IV	NO	Vapour Lock Index	C	LV	NO
Cloud Point	G	IV	NO				
(1) Property Type: G = Generic, E = Evaporate, C = Composite							
(2) Mixing Rule: LV = Linear Volume, LW = Linear Weight, IV = Index Volume IW = Index Weight							
(3) Use volume factor (YES / NO)							
(4) Added with 0.5 cc of Tetra Methyl Lead / Tetra Ethyl Lead per Litre							

Table 4 – Predefined Property Mixing Rules

PERIODS

The Blending Problem is managed on a Multi Period Base: for each period specified in the simulation (Figure 7) it is necessary to define the corresponding duration (in days). Depending on the length of the periods the application may support the scheduling of short (for instance a week as in the example), medium or short-medium term cases (a sequence of short duration periods joined with a sequence of long period).



Name	Unit	1	2	3	4	5	6	7
Description		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Duration	[Day]	1	1	1	1	1	1	1
Start		10/03/2008	11/03/2008	12/03/2008	13/03/2008	14/03/2008	15/03/2008	16/03/2008
End		10/03/2008	11/03/2008	12/03/2008	13/03/2008	14/03/2008	15/03/2008	16/03/2008

Figure 7 - Simulation Periods

Multi Period representation permits to manage the blending problem with an holistic approach, and this may constitute and advantage respect to in-line blending: components are used not only to adjust the current formulation but are managed considering also future periods expected schedule; especially in case of components shortage an overview of next future operation may provide tangible advantages.

Increasing the number of periods means to increase problem dimension and it results time expensive for matrix solving process (especially in case of MIP cases with many Integer Variables), thus a good compromise between number of periods and detail of schedule must be found.

For each period defined it is possible to set Capacity and Economics constraints of each object involved in the simulation (blending components, finished products, tanks, groups, etc.). When they are not set, the previous period data are considered.

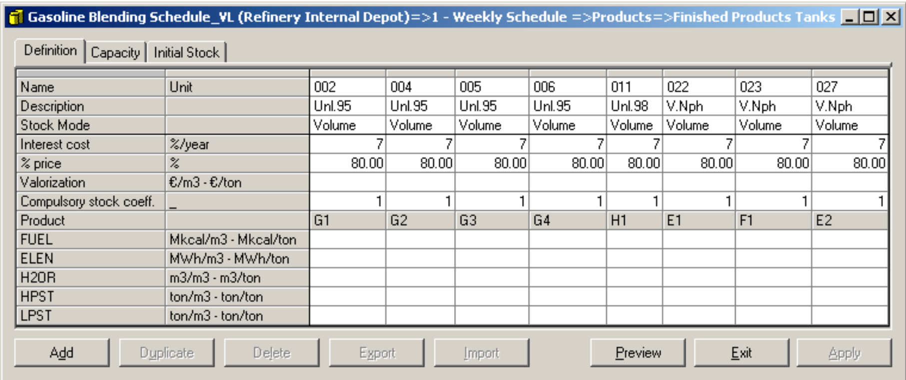
TANKS

Tanks objects are available to simulate the logistics of Blending Operation and are used either to set capacity constraints (minimum and maximum quantities) and to specify – in case of product tanks – the quantity and the quality of the tank bottom that is to be included in product formulation.

Besides Tank's Stock Mode (defining whether capacity data are handled in weight or volume base), additional parameters are set to account for immobilisation costs, to quantify Tank's content economic value (at the beginning of the first period and at the end of the last period) and to simulate the specific utility consumption associated to the usage of each tank.

Product Tanks definition mask is showed in Figure 8: any finished product is compulsorily associated to a tank.

In this specific example, immobilisation costs are accounted for the 7 % per year of Tank content's value that is set to be equal to the 80 % of product's sale price.



Name	Unit	002	004	005	006	011	022	023	027
Description		Unl.95	Unl.95	Unl.95	Unl.95	Unl.98	V.Nph	V.Nph	V.Nph
Stock Mode		Volume	Volume	Volume	Volume	Volume	Volume	Volume	Volume
Interest cost	%/year	7	7	7	7	7	7	7	7
% price	%	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Valorization	€/m3 - €/ton								
Compulsory stock coeff.	_	1	1	1	1	1	1	1	1
Product		G1	G2	G3	G4	H1	E1	F1	E2
FUEL	Mkcal/m3 - Mkcal/ton								
ELEN	MWh/m3 - MWh/ton								
H2OR	m3/m3 - m3/ton								
HPST	ton/m3 - ton/ton								
LPST	ton/m3 - ton/ton								

Figure 8 - Product tank Definition

Tank bottom is automatically included with its specific quality in product formulation; corresponding data can be either entered or imported from Refinery Information System (Figure *9*). The system permits also to estimate unknown or not updated information using Library data that are built through historical databases.

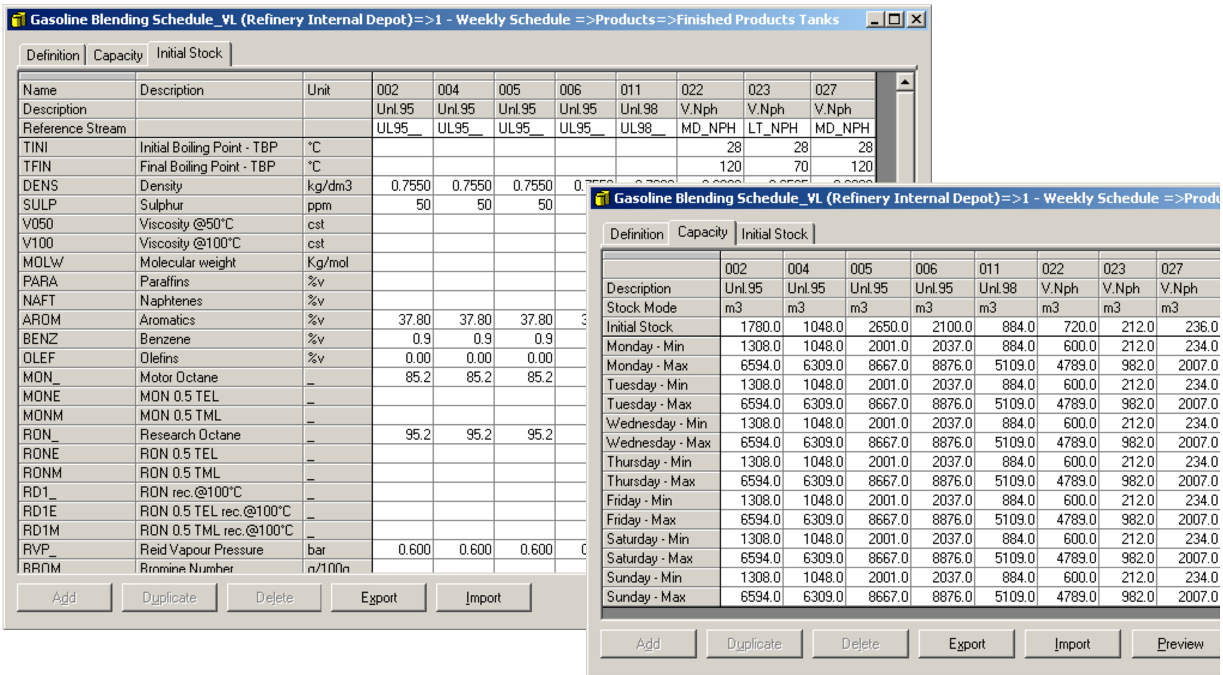


Figure 9 – Tank Bottom Quality and Initial Stock

<u>Blending Components Availability and Production Constraints (Economics)</u>

<u>Prices</u>

The Optimisation problem is focused on the Blending Department, as if it was an independent company buying intermediate and selling finished products; thus it is necessary to define purchase and sale prices for each object involved.

The economical value given to intermediate and finished products is very important since it constitutes the real “driving force” of the optimisation process; if in case of finished products it is possible to consider market sale prices, a direct reference for Intermediates purchase prices is not available, either because an “intermediates market” does not exist in reality, either because the real value (for the refinery) depends on many factors linked to refinery operation and market.

A reasonable approach, assuring uniformity with Refinery Planning Models, consists in using the “shadow values” calculated for each intermediate by the LP Model: these data represent the calculated value of each intermediate product and are retrievable from of Refinery LP Model Results.

While getting these data attention must be paid to the reliability of the solution: sometimes, not well consolidated LP simulations may contain unreasonable “shadow values” due to a “stressed” solution: that is why prices definition is a job that should be handled by the Planning Department that is charged to produce (weekly, monthly depending on Refinery

Consolidated habits) the set of reference prices for intermediate and finished product to be used for Blending Optimisation.

The set of prices used for this example is reported in Table 5: being the simulation aimed to the development of a weekly schedule, prices have been kept constant in time; exercises aimed to simulate longer periods of time may also account for expected market fluctuations by setting different prices in different periods.

PRODUCT	TYPE	PURCHASE PRICE [€/m3]	SALE PRICE [€/m3]
Butane	Intermediate	192.38	-
MTBE	Intermediate	415.66	-
Isomerate	Intermediate	242.29	-
SR L.Naphtha	Intermediate	235.53	-
SR M.Naphtha	Intermediate	259.55	-
SR H.Naphtha	Intermediate	273.54	-
DH Bottom	Intermediate	265.69	-
Reformate + IC5	Intermediate	357.82	-
Heavy Naphtha	Finished	-	254.43
Light Naphtha	Finished	-	265.43
Unleaded Gasoline (95)	Finished	-	329.48
Unleaded Plus Gasoline (98)	Finished	-	368.89

Table 5 - Intermediate and Finished Product Prices

QUANTITIES

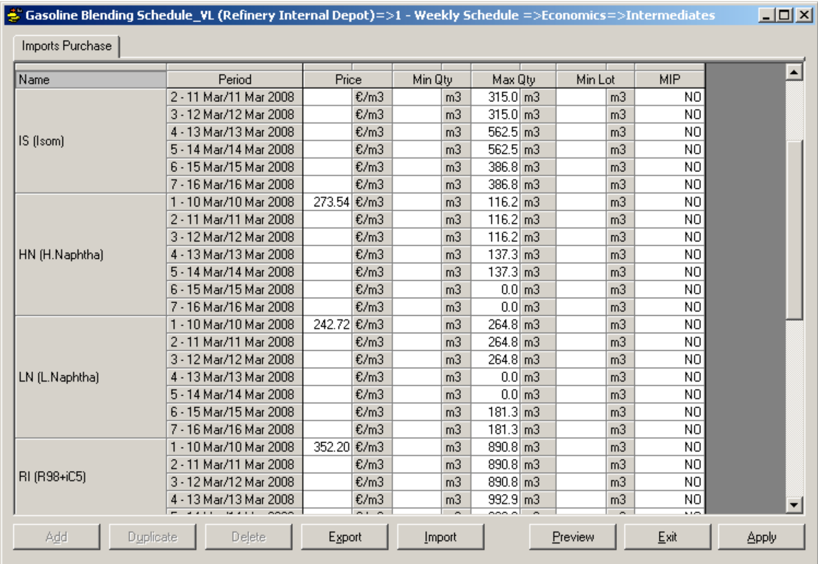
Quantity constraints are provided either to define intermediates availability and to set minimum and maximum productions: not providing a number means to assume an unbounded quantity.

The availability of blending components is given by the amount available at the beginning of the simulation (specified as “initial stock” in the intermediate tanks) plus the quantities produced by plants during each period: these last are considered to be “purchased” in bounded quantities, considering the amounts calculated by the scheduling model.

Figure 10 shows the form dedicated to the input of intermediate products economics: depending on specific scheduling needs two alternative approaches can be applied for intermediate products management:

- The amounts produced by the plants are fixed (Minimum Quantity equal to Maximum Quantity) in order to force the Model to utilise them even if it results not profitable: in this case formulations are less driven by the value of intermediate products and the Model optimises the management of storage facilities (*Plant Driven Approach*)
- The amounts produced by the plants are upper bounded (Minimum Quantity unbounded) permitting the Model to utilise them only if it results profitable: in this case formulations are mainly driven by the value of intermediate and finished products (*Economics Driven Approach*).

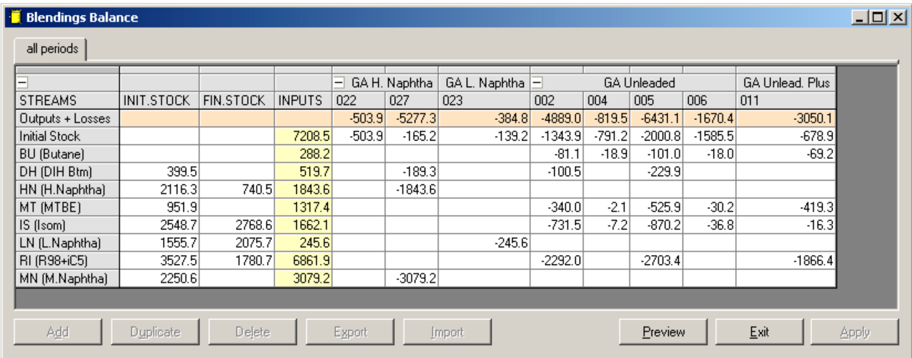
Through Figures 10 and 11 it is possible to compare the operation summaries resulting from the two different approaches (being unchanged all other constraints); obviously a mixed approach is applicable too (some intermediates fixed and some free).


Gasoline Blending Schedule_VL (Refinery Internal Depot)=>1 - Weekly Schedule =>Economics=>Intermediates

Imports Purchase

Name	Period	Price		Min Qty		Max Qty		Min Lot		MIP
IS (Isom)	2 - 11 Mar/11 Mar 2008		€/m3		m3	315.0	m3		m3	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	315.0	m3		m3	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	562.5	m3		m3	NO
	5 - 14 Mar/14 Mar 2008		€/m3		m3	562.5	m3		m3	NO
	6 - 15 Mar/15 Mar 2008		€/m3		m3	386.8	m3		m3	NO
	7 - 16 Mar/16 Mar 2008		€/m3		m3	386.8	m3		m3	NO
HN (H.Naphtha)	1 - 10 Mar/10 Mar 2008	273.54	€/m3		m3	116.2	m3		m3	NO
	2 - 11 Mar/11 Mar 2008		€/m3		m3	116.2	m3		m3	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	116.2	m3		m3	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	137.3	m3		m3	NO
	5 - 14 Mar/14 Mar 2008		€/m3		m3	137.3	m3		m3	NO
	6 - 15 Mar/15 Mar 2008		€/m3		m3	0.0	m3		m3	NO
	7 - 16 Mar/16 Mar 2008		€/m3		m3	0.0	m3		m3	NO
LN (L.Naphtha)	1 - 10 Mar/10 Mar 2008	242.72	€/m3		m3	264.8	m3		m3	NO
	2 - 11 Mar/11 Mar 2008		€/m3		m3	264.8	m3		m3	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	264.8	m3		m3	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	0.0	m3		m3	NO
	5 - 14 Mar/14 Mar 2008		€/m3		m3	0.0	m3		m3	NO
	6 - 15 Mar/15 Mar 2008		€/m3		m3	181.3	m3		m3	NO
	7 - 16 Mar/16 Mar 2008		€/m3		m3	181.3	m3		m3	NO
RI (R98+iC5)	1 - 10 Mar/10 Mar 2008	352.20	€/m3		m3	890.8	m3		m3	NO
	2 - 11 Mar/11 Mar 2008		€/m3		m3	890.8	m3		m3	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	890.8	m3		m3	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	992.9	m3		m3	NO

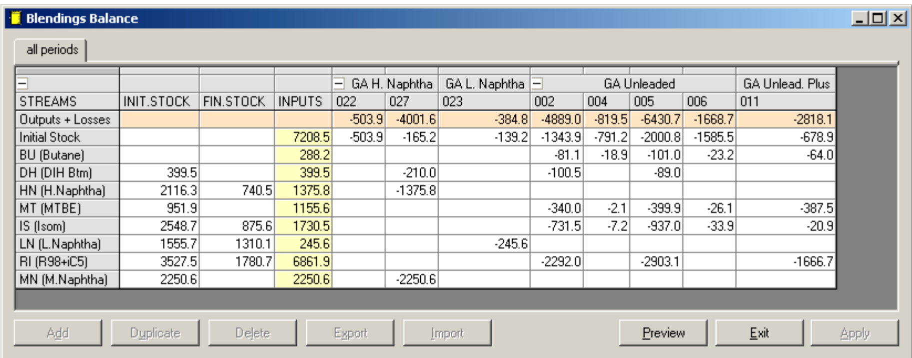
Figure 10 - Intermediate Products Economics


Blendings Balance

all periods

				GA H. Naphtha		GA L. Naphtha	GA Unleaded				GA Unlead. Plus
STREAMS	INIT.STOCK	FIN.STOCK	INPUTS	022	027	023	002	004	005	006	011
Outputs + Losses				-503.9	-5277.3	-384.8	-4889.0	-819.5	-6431.1	-1670.4	-3050.1
Initial Stock			7208.5	-503.9	-165.2	-139.2	-1343.9	-791.2	-2000.8	-1585.5	-678.9
BU (Butane)			288.2				-81.1	-18.9	-101.0	-18.0	-69.2
DH (DIH Btm)	399.5		519.7		-189.3		-100.5		-229.9		
HN (H.Naphtha)	2116.3	740.5	1843.6		-1843.6						
MT (MTBE)	951.9		1317.4				-340.0	-2.1	-525.9	-30.2	-419.3
IS (Isom)	2548.7	2768.6	1662.1				-731.5	-7.2	-870.2	-36.8	-16.3
LN (L.Naphtha)	1555.7	2075.7	245.6			-245.6					
RI (R98+iC5)	3527.5	1780.7	6861.9				-2292.0		-2703.4		-1866.4
MN (M.Naphtha)	2250.6		3079.2		-3079.2						

Figure 11 - Operation Summary in case of Plant Driven Approach

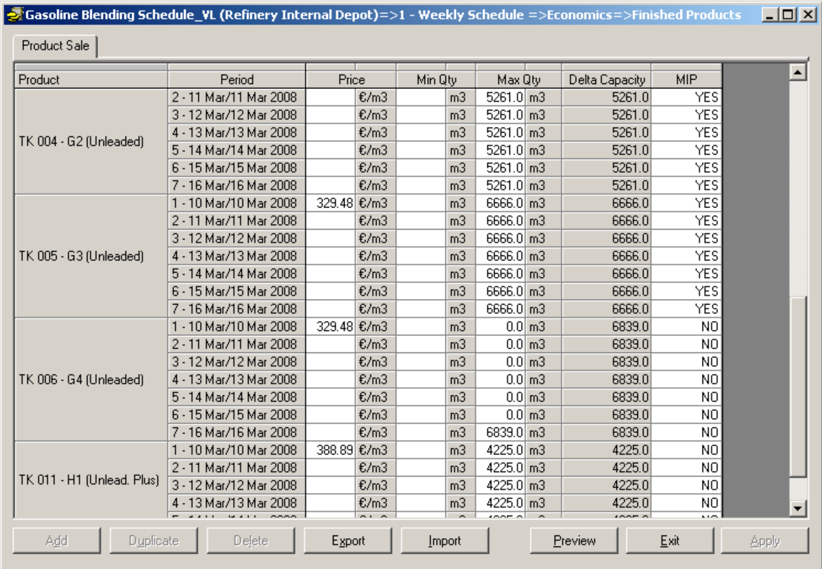

Blendings Balance

all periods

				GA H. Naphtha		GA L. Naphtha	GA Unleaded				GA Unlead. Plus
STREAMS	INIT.STOCK	FIN.STOCK	INPUTS	022	027	023	002	004	005	006	011
Outputs + Losses				-503.9	-4001.6	-384.8	-4889.0	-819.5	-6430.7	-1668.7	-2818.1
Initial Stock			7208.5	-503.9	-165.2	-139.2	-1343.9	-791.2	-2000.8	-1585.5	-678.9
BU (Butane)			288.2				-81.1	-18.9	-101.0	-23.2	-64.0
DH (DIH Btm)	399.5		399.5		-210.0		-100.5		-89.0		
HN (H.Naphtha)	2116.3	740.5	1375.8		-1375.8						
MT (MTBE)	951.9		1155.6				-340.0	-2.1	-399.9	-26.1	-387.5
IS (Isom)	2548.7	875.6	1730.5				-731.5	-7.2	-937.0	-33.9	-20.9
LN (L.Naphtha)	1555.7	1310.1	245.6			-245.6					
RI (R98+iC5)	3527.5	1780.7	6861.9				-2292.0		-2903.1		-1666.7
MN (M.Naphtha)	2250.6		2250.6		-2250.6						

Figure 12 Operation Summary in case of Economics Driven Approach

Figure 13 shows the form dedicated to the input of finished products economics: besides price and min/max columns the "Delta Capacity" (maximum capacity minus minimum capacity) of the tank associated the product is reported as well as the MIP mode meaning if the sell is to be managed as an integer variable (the program is allowed to sell the product only if the tank is full) or not.



Product	Period	Price		Min Qty		Max Qty		Delta Capacity	MIP
TK 004 - G2 (Unleaded)	2 - 11 Mar/11 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
	3 - 12 Mar/12 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
	4 - 13 Mar/13 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
	5 - 14 Mar/14 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
	6 - 15 Mar/15 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
	7 - 16 Mar/16 Mar 2008		€/m3		m3	5261.0	m3	5261.0	YES
TK 005 - G3 (Unleaded)	1 - 10 Mar/10 Mar 2008	329.48	€/m3		m3	6666.0	m3	6666.0	YES
	2 - 11 Mar/11 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
	3 - 12 Mar/12 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
	4 - 13 Mar/13 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
	5 - 14 Mar/14 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
	6 - 15 Mar/15 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
	7 - 16 Mar/16 Mar 2008		€/m3		m3	6666.0	m3	6666.0	YES
TK 006 - G4 (Unleaded)	1 - 10 Mar/10 Mar 2008	329.48	€/m3		m3	0.0	m3	6839.0	NO
	2 - 11 Mar/11 Mar 2008		€/m3		m3	0.0	m3	6839.0	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	0.0	m3	6839.0	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	0.0	m3	6839.0	NO
	5 - 14 Mar/14 Mar 2008		€/m3		m3	0.0	m3	6839.0	NO
	6 - 15 Mar/15 Mar 2008		€/m3		m3	0.0	m3	6839.0	NO
	7 - 16 Mar/16 Mar 2008		€/m3		m3	6839.0	m3	6839.0	NO
TK 011 - H1 (Unlead. Plus)	1 - 10 Mar/10 Mar 2008	388.89	€/m3		m3	4225.0	m3	4225.0	NO
	2 - 11 Mar/11 Mar 2008		€/m3		m3	4225.0	m3	4225.0	NO
	3 - 12 Mar/12 Mar 2008		€/m3		m3	4225.0	m3	4225.0	NO
	4 - 13 Mar/13 Mar 2008		€/m3		m3	4225.0	m3	4225.0	NO

Figure 13 - Finished Products Economics

<u>GENERAL BOUNDS</u>

Sometimes it is necessary to specify capacity bounds for a group of objects: for example, the Blending Operator might be interested in producing a given amount of product without caring of which tanks will be used for this purpose or better, he might be interested in knowing which sequence of tanks is most profitable to prepare in the forthcoming week: General Bounds permit to group together under the same capacity constraint more objects (finished product tanks in this case).

Figure 14 shows General Bounds Definition Form: in this specific example a General Bound has been defined for every product grade, grouping together the tanks associated to the same grade.

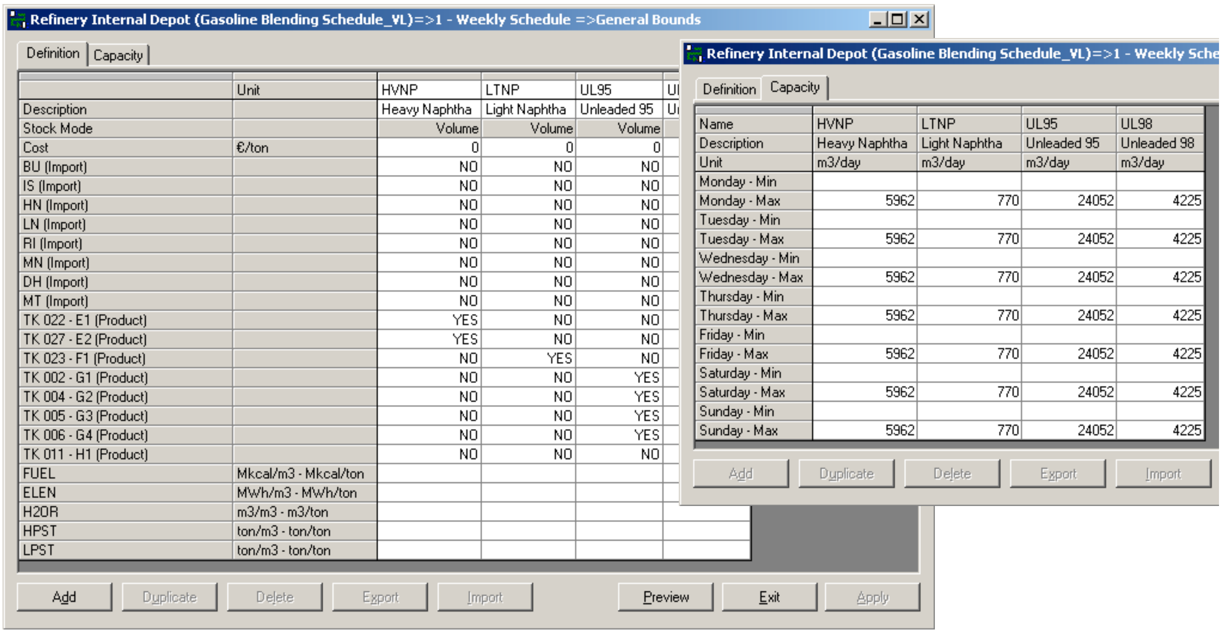


Figure 14 General Bounds Definition

Similarly it is possible to set capacity bounds grouping together more periods, in case that the Blending Operator was not interested in specifying when a given amount of product will be exactly shipped provided that that amount will be prepared by a given date.

INTEGRATION WITH REFINERY INFORMATION SYSTEM

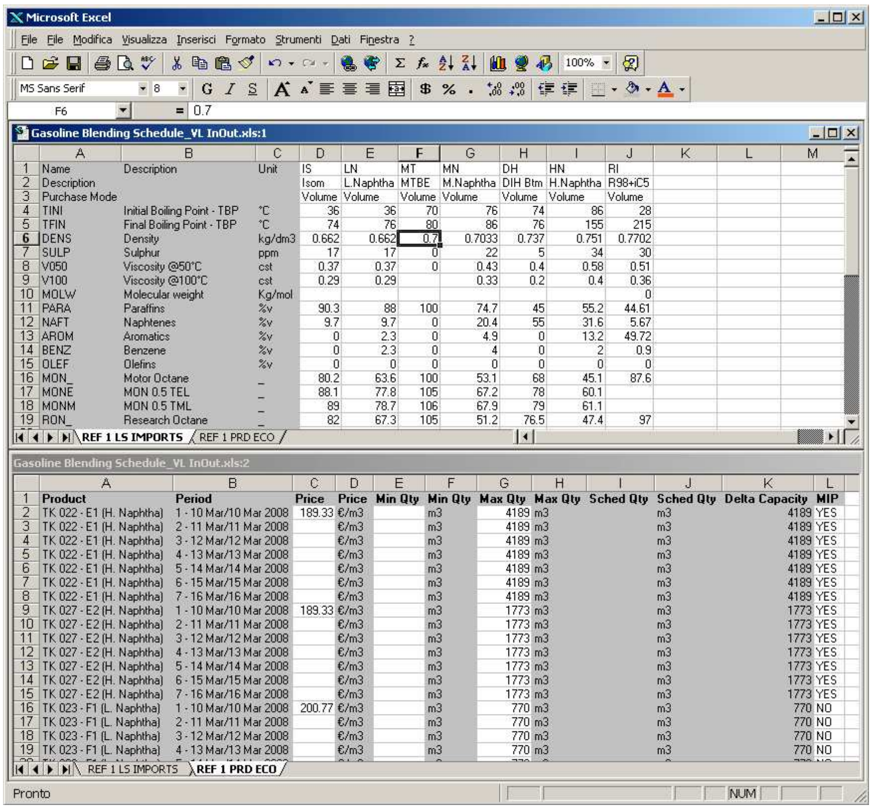
To be really usable in the ordinary planning practice, the system must be integrated with Information System of the Refinery, in order to get automatically the data useful to perform the simulation and to minimise direct data entering.

The program is equipped with import/export functions permitting to write to and read from MS Excel Files (see Figure 15).

Within Excel Environment it is possible to build automation procedures retrieving data from the Refinery Information System and preparing these transfer Files in a format easily read by the application.

Data to be retrieved from the information system are:

- Intermediates and Tank quality data: from laboratory database
- Intermediates expected availability: form short term scheduling applications
- Tank status data: from tank management systems
- Prices and shipping schedule: from planning and scheduling applications.



	A	B	C	D	E	F	G	H	I	J
1	Name	Description	Unit	IS	LN	MT	MN	DH	HN	RI
2	Description			Isom	L.Naphtha	MTBE	M.Naphtha	DIH Btm	H.Naphtha	R98+iC5
3	Purchase Mode			Volume	Volume	Volume	Volume	Volume	Volume	Volume
4	TINI	Initial Boiling Point - TBP	°C	36	36	70	76	74	86	28
5	TFIN	Final Boiling Point - TBP	°C	74	76	80	86	76	155	215
6	DENS	Density	kg/dm3	0.662	0.662	0.7	0.7033	0.737	0.751	0.7702
7	SULP	Sulphur	ppm	17	17	0	22	5	34	30
8	V050	Viscosity @50°C	cst	0.37	0.37	0	0.43	0.4	0.58	0.51
9	V100	Viscosity @100°C	cst	0.29	0.29		0.33	0.2	0.4	0.36
10	MOLW	Molecular weight	Kg/mol							0
11	PARA	Paraffins	%v	90.3	88	100	74.7	45	55.2	44.61
12	NAFT	Naphtenes	%v	9.7	9.7	0	20.4	55	31.6	5.67
13	AROM	Aromatics	%v	0	2.3	0	4.9	0	13.2	49.72
14	BENZ	Benzene	%v	0	2.3	0	4	0	2	0.9
15	OLEF	Olefins	%v	0	0	0	0	0	0	0
16	MON_	Motor Octane	_	80.2	63.6	100	53.1	68	45.1	87.6
17	MONE	MON 0.5 TEL	_	88.1	77.8	105	67.2	78	60.1	
18	MONM	MON 0.5 TML	_	89	78.7	106	67.9	79	61.1	
19	RON_	Research Octane	_	82	67.3	105	51.2	76.5	47.4	97

	A	B	C	D	E	F	G	H	I	J	K	L
1	Product	Period	Price	Price	Min Qty	Min Qty	Max Qty	Max Qty	Sched Qty	Sched Qty	Delta Capacity	MIP
2	TK 022 - E1 (H. Naphtha)	1 - 10 Mar/10 Mar 2008	189.33	€/m3		m3	4189	m3		m3	4189	YES
3	TK 022 - E1 (H. Naphtha)	2 - 11 Mar/11 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
4	TK 022 - E1 (H. Naphtha)	3 - 12 Mar/12 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
5	TK 022 - E1 (H. Naphtha)	4 - 13 Mar/13 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
6	TK 022 - E1 (H. Naphtha)	5 - 14 Mar/14 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
7	TK 022 - E1 (H. Naphtha)	6 - 15 Mar/15 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
8	TK 022 - E1 (H. Naphtha)	7 - 16 Mar/16 Mar 2008		€/m3		m3	4189	m3		m3	4189	YES
9	TK 027 - E2 (H. Naphtha)	1 - 10 Mar/10 Mar 2008	189.33	€/m3		m3	1773	m3		m3	1773	YES
10	TK 027 - E2 (H. Naphtha)	2 - 11 Mar/11 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
11	TK 027 - E2 (H. Naphtha)	3 - 12 Mar/12 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
12	TK 027 - E2 (H. Naphtha)	4 - 13 Mar/13 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
13	TK 027 - E2 (H. Naphtha)	5 - 14 Mar/14 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
14	TK 027 - E2 (H. Naphtha)	6 - 15 Mar/15 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
15	TK 027 - E2 (H. Naphtha)	7 - 16 Mar/16 Mar 2008		€/m3		m3	1773	m3		m3	1773	YES
16	TK 023 - F1 (L. Naphtha)	1 - 10 Mar/10 Mar 2008	200.77	€/m3		m3	770	m3		m3	770	NO
17	TK 023 - F1 (L. Naphtha)	2 - 11 Mar/11 Mar 2008		€/m3		m3	770	m3		m3	770	NO
18	TK 023 - F1 (L. Naphtha)	3 - 12 Mar/12 Mar 2008		€/m3		m3	770	m3		m3	770	NO
19	TK 023 - F1 (L. Naphtha)	4 - 13 Mar/13 Mar 2008		€/m3		m3	770	m3		m3	770	NO

Figure 15 Data Exchange via MS Excel

MATRIX GENERATION AND OPTIMISATION PROCESSES

Running the Optimisation Process the system automatically generates a Linear Programming Matrix representing the blending problem.

In our example the Blending problem is represented by about 1200 balances, 900 variables (of whom 30 to 60, depending on the number of objects handled in MIP mode, are Integer), and 6700 coefficients.

The problem is solved using a commercial solver (LINDO API): two alternative Optimisation Algorithms are available: Pure Linear Programming and Mixed Integer Programming (that is mandatory to perform MIP functions).

The problem is solved in less than one second with the LP algorithm and in about one minute with the MIP algorithm (depending on the number of integer variables used in the specific case).

In case of infeasible problems, the system provides a report detailing which constraints have caused the infeasibility. Figure 17 shows the report produced by the program in case of incapacity to produce the specified amount of products on specification (being the limiting specification Research Octane Number): the report highlights the volume balance of the product, the balance of product specification and the maximum composition bound set for

MTBE, that is the component used by the model to raise the octane number of the mixture to the desired level.

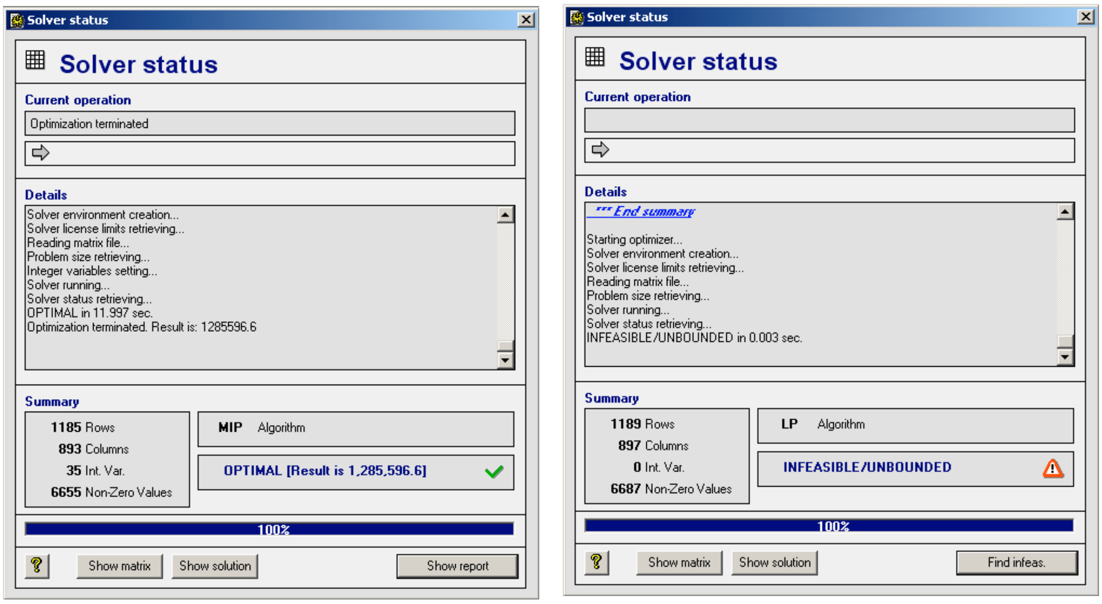
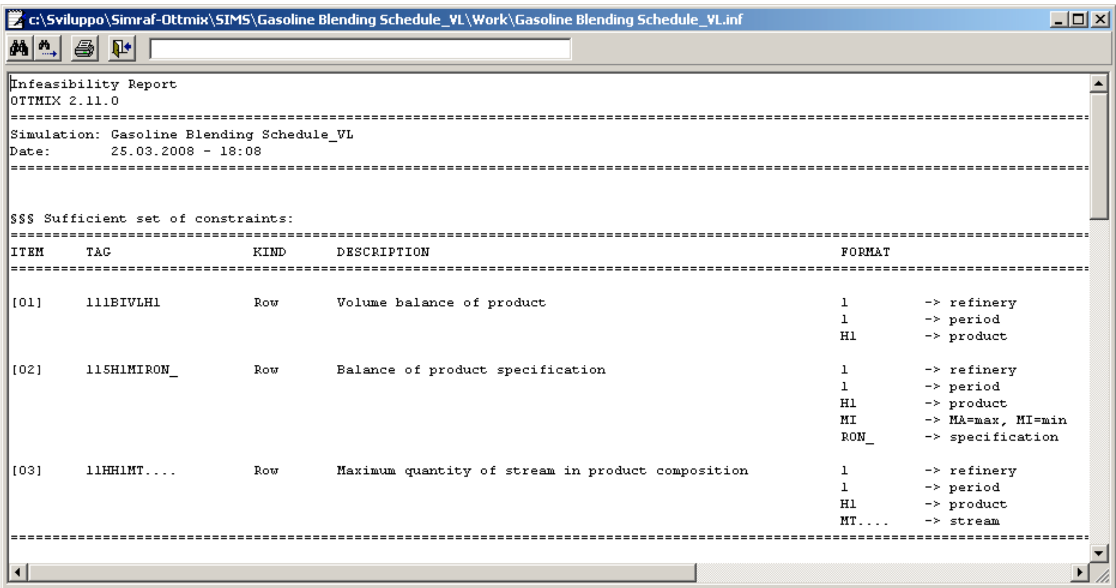


Figure 16 – Example of Optimisation Process Reports



```
c:\Sviluppo\Simraf-Ottmix\SIMS\Gasoline Blending Schedule_VL\Work\Gasoline Blending Schedule_VL.inf

Infeasibility Report
OTTMIX 2.11.0
==========================================================================================
Simulation: Gasoline Blending Schedule_VL
Date:       25.03.2008 - 18:08
==========================================================================================

$$$ Sufficient set of constraints:
==========================================================================================
ITEM     TAG                KIND      DESCRIPTION                                   FORMAT
==========================================================================================

[01]     111BIVLH1          Row       Volume balance of product                     1       -> refinery
                                                                                    1       -> period
                                                                                    H1      -> product

[02]     115H1MIRON_        Row       Balance of product specification              1       -> refinery
                                                                                    1       -> period
                                                                                    H1      -> product
                                                                                    MI      -> MA=max, MI=min
                                                                                    RON_    -> specification

[03]     11HH1MT....        Row       Maximum quantity of stream in product composition  1  -> refinery
                                                                                    1       -> period
                                                                                    H1      -> product
                                                                                    MT....  -> stream
==========================================================================================
```

Figure 17 - Infeasibility Report Example

Results

The application produces many reports providing any information useful to define the production schedule. Each report details the operating asset suggested by the optimal solution either for one specific period and for the global schedule (all the periods defined in the simulation). All the reports are automatically elaborated by the system after optimisation run and can be examined upon request.

Reports can be considered of the following types:

- *Economical Reports*: detailing the economical result of each period in terms of purchased components, shipped products, operative and immobilisation costs and stock valorisation (Figure 18).

Economic Balance

Economic Balance in period '1'

INTERMEDIATES/PRODUCTS	ACQUIRED QTY ton	DELIVERED QTY ton	PRICE €/ton	TOTAL €	INCR.VALUE €/ton
Butane	106.1		251.76	-26706.44	232.95
DIH Btm	23.6		277.69	-6549.12	76.55
H.Naphtha	87.2		274.25	-23911.96	-54.89
MTBE			554.79		-0.03
Isom	208.5		284.06	-59217.01	-56.86
L.Naphtha	175.2		274.24	-48056.18	-54.89
R98+iC5	686.1		340.72	-233763.70	169.50
M.Naphtha	105.2		274.25	-28854.94	-40.02
TK 022 - H. Naphtha			270.55		54.47
TK 027 - H. Naphtha		1286.7	260.89	335682.10	33.89
TK 023 - L. Naphtha		244.9	304.20	74487.38	
TK 002 - Unleaded			369.81		0.36
TK 004 - Unleaded			370.55		140.85
TK 005 - Unleaded			370.85		0.17
TK 006 - Unleaded			371.25		0.43
TK 011 - Unlead. Plus		1503.9	386.28	580927.30	-138.27
Gross Total	1391.9	3035.5		564037.40	
Financial Costs				-614.73	
Initial Stock Value				573076.40	
Final Stock Value				6710622.00	
Total Result				5304654.00	

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Figure 18 - Economic Balance example

- *Operative Reports*: summarising the quantities handled to produce each finished product in a given period (Figure 19) and – on a multi period base – the status of each intermediate and finished product tank accounting for purchasing, blending and shipping operations (Figure 20).

Blendings Balance

Blendings Material Balance in period '1'

				GA H. Naphtha		GA L. Naphtha	GA Unleaded				GA Unlead. Plus
STREAMS	INIT.STOCK	FIN.STOCK	INPUTS	022	027	023	002	004	005	006	011
Outputs + Losses				-503.9	-1456.5	-384.8	-1437.2	-819.3	-2266.4	-1682.1	-2168.6
Initial Stock			7208.5	-503.9	-165.2	-139.2	-1343.9	-791.2	-2000.8	-1585.5	-678.9
BU (Butane)			106.1					-18.9		-37.5	-49.7
DH (DIH Btm)	399.5	388.2	34.9						-34.9		
HN (H.Naphtha)	2116.3	1482.1	721.4		-721.4						
MT (MTBE)	893.2	386.5	506.7				-48.1	-2.0	-146.6	-27.4	-282.6
IS (Isom)	2548.7	2615.1	142.0				-36.2	-7.2	-42.6	-22.5	-33.4
LN (L.Naphtha)	1555.7	1485.3	245.6			-245.6					
RI (R98+iC5)	3527.5	3089.7	1123.9								-1123.9
MN (M.Naphtha)	2250.6	1726.1	629.7		-570.0		-9.0		-41.5	-9.2	

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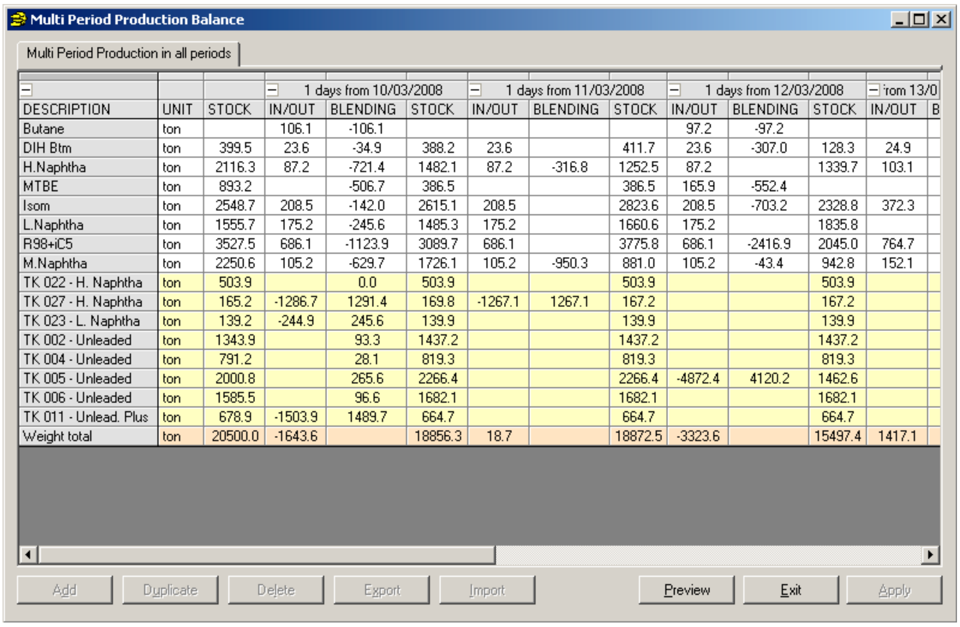
Figure 19 - Blendings Balance example



Multi Period Production Balance

Multi Period Production in all periods

			1 days from 10/03/2008			1 days from 11/03/2008			1 days from 12/03/2008			'rom 13/0
DESCRIPTION	UNIT	STOCK	IN/OUT	BLENDING	STOCK	IN/OUT	BLENDING	STOCK	IN/OUT	BLENDING	STOCK	IN/OUT
Butane	ton		106.1	-106.1					97.2	-97.2		
DIH Btm	ton	399.5	23.6	-34.9	388.2	23.6		411.7	23.6	-307.0	128.3	24.9
H.Naphtha	ton	2116.3	87.2	-721.4	1482.1	87.2	-316.8	1252.5	87.2		1339.7	103.1
MTBE	ton	893.2		-506.7	386.5			386.5	165.9	-552.4		
Isom	ton	2548.7	208.5	-142.0	2615.1	208.5		2823.6	208.5	-703.2	2328.8	372.3
L.Naphtha	ton	1555.7	175.2	-245.6	1485.3	175.2		1660.6	175.2		1835.8	
R98+iC5	ton	3527.5	686.1	-1123.9	3089.7	686.1		3775.8	686.1	-2416.9	2045.0	764.7
M.Naphtha	ton	2250.6	105.2	-629.7	1726.1	105.2	-950.3	881.0	105.2	-43.4	942.8	152.1
TK 022 - H. Naphtha	ton	503.9		0.0	503.9			503.9			503.9	
TK 027 - H. Naphtha	ton	165.2	-1286.7	1291.4	169.8	-1267.1	1267.1	167.2			167.2	
TK 023 - L. Naphtha	ton	139.2	-244.9	245.6	139.9			139.9			139.9	
TK 002 - Unleaded	ton	1343.9		93.3	1437.2			1437.2			1437.2	
TK 004 - Unleaded	ton	791.2		28.1	819.3			819.3			819.3	
TK 005 - Unleaded	ton	2000.8		265.6	2266.4			2266.4	-4872.4	4120.2	1462.6	
TK 006 - Unleaded	ton	1585.5		96.6	1682.1			1682.1			1682.1	
TK 011 - Unlead. Plus	ton	678.9	-1503.9	1489.7	664.7			664.7			664.7	
Weight total	ton	20500.0	-1643.6		18856.3	18.7		18872.5	-3323.6		15497.4	1417.1

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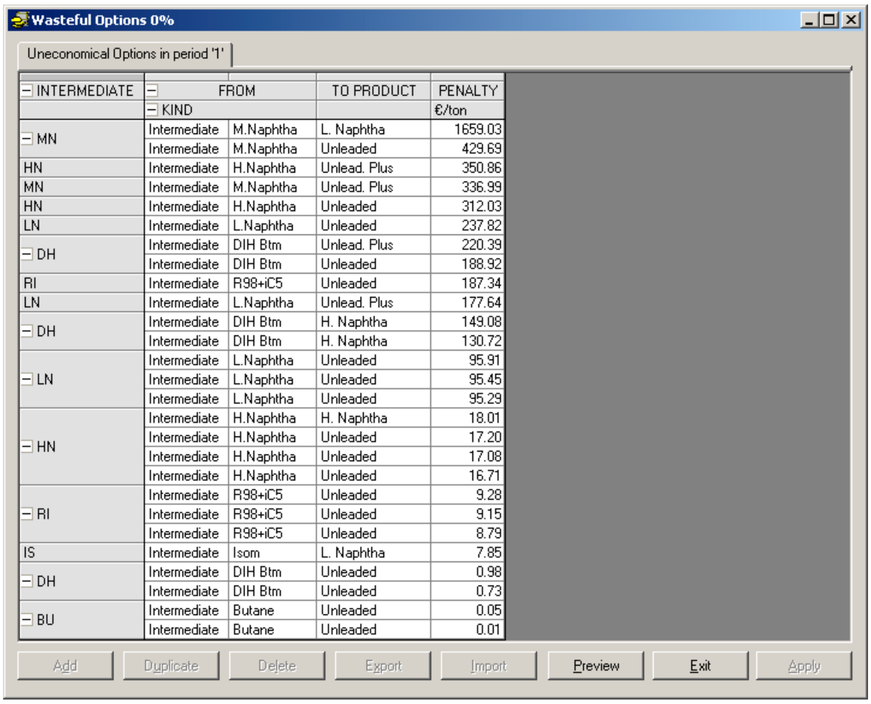
Figure 20 - Multi Period Production Balance example

- *Solution Analysis Reports*: analysis of the marginal values contained in the solution aimed to highlight the constraints limiting the results, blending components shadow values and the blending options that have been excluded by the model resulting unprofitable (Figure 21).



Wasteful Options 0%

Uneconomical Options in period '1'

INTERMEDIATE	FROM		TO PRODUCT	PENALTY
	KIND			€/ton
MN	Intermediate	M.Naphtha	L. Naphtha	1659.03
	Intermediate	M.Naphtha	Unleaded	429.69
HN	Intermediate	H.Naphtha	Unlead. Plus	350.86
MN	Intermediate	M.Naphtha	Unlead. Plus	336.99
HN	Intermediate	H.Naphtha	Unleaded	312.03
LN	Intermediate	L.Naphtha	Unleaded	237.82
DH	Intermediate	DIH Btm	Unlead. Plus	220.39
	Intermediate	DIH Btm	Unleaded	188.92
RI	Intermediate	R98+iC5	Unleaded	187.34
LN	Intermediate	L.Naphtha	Unlead. Plus	177.64
DH	Intermediate	DIH Btm	H. Naphtha	149.08
	Intermediate	DIH Btm	H. Naphtha	130.72
LN	Intermediate	L.Naphtha	Unleaded	95.91
	Intermediate	L.Naphtha	Unleaded	95.45
	Intermediate	L.Naphtha	Unleaded	95.29
HN	Intermediate	H.Naphtha	H. Naphtha	18.01
	Intermediate	H.Naphtha	Unleaded	17.20
	Intermediate	H.Naphtha	Unleaded	17.08
	Intermediate	H.Naphtha	Unleaded	16.71
RI	Intermediate	R98+iC5	Unleaded	9.28
	Intermediate	R98+iC5	Unleaded	9.15
	Intermediate	R98+iC5	Unleaded	8.79
IS	Intermediate	Isom	L. Naphtha	7.85
DH	Intermediate	DIH Btm	Unleaded	0.98
	Intermediate	DIH Btm	Unleaded	0.73
BU	Intermediate	Butane	Unleaded	0.05
	Intermediate	Butane	Unleaded	0.01

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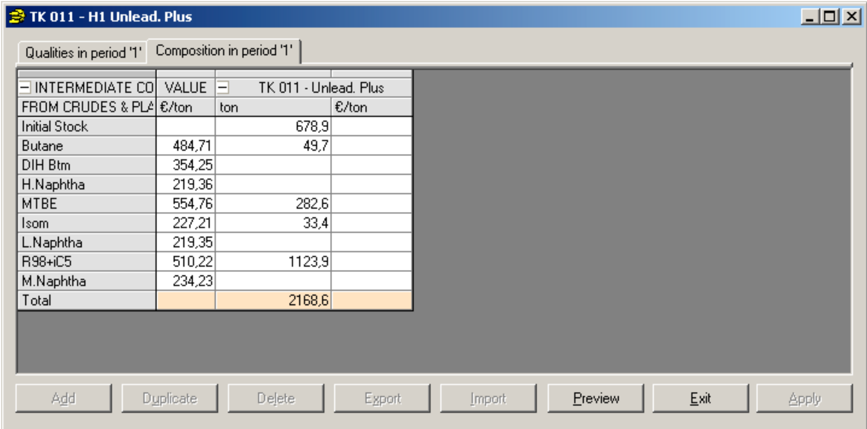
Figure 21 - Wasteful Options Report Example

- *Products Reports*: Available only on single period base, these reports details the suggested blending recipe (Figure 22) and the calculated quality (Figure 23) for each product produced in the period.



TK 011 - H1 Unlead. Plus

Qualities in period '1' | Composition in period '1'

INTERMEDIATE CO	VALUE	TK 011 - Unlead. Plus	
FROM CRUDES & PLA	€/ton	ton	€/ton
Initial Stock		678,9	
Butane	484,71	49,7	
DIH Btm	354,25		
H.Naphtha	219,36		
MTBE	554,76	282,6	
Isom	227,21	33,4	
L.Naphtha	219,35		
R98+iC5	510,22	1123,9	
M.Naphtha	234,23		
Total		2168,6	

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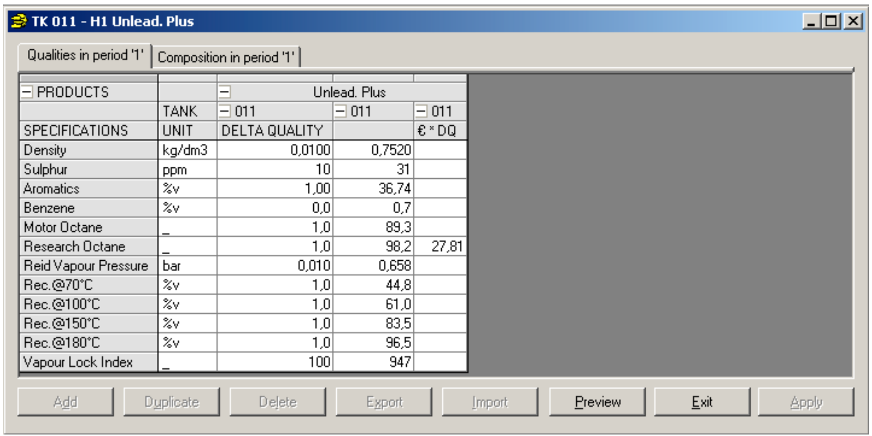
Figure 22 - Finished Product Composition



TK 011 - H1 Unlead. Plus

Qualities in period '1' | Composition in period '1'

PRODUCTS		Unlead. Plus		
	TANK	011	011	011
SPECIFICATIONS	UNIT	DELTA QUALITY		€ * DQ
Density	kg/dm3	0,0100	0,7520	
Sulphur	ppm	10	31	
Aromatics	%v	1,00	36,74	
Benzene	%v	0,0	0,7	
Motor Octane	_	1,0	89,3	
Research Octane	_	1,0	98,2	27,81
Reid Vapour Pressure	bar	0,010	0,658	
Rec.@70°C	%v	1,0	44,8	
Rec.@100°C	%v	1,0	61,0	
Rec.@150°C	%v	1,0	83,5	
Rec.@180°C	%v	1,0	96,5	
Vapour Lock Index	_	100	947	

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Figure 23 - Finished Product Quality

IMPACT OF ALTERNATIVE MARKET SCENARIOS

To demonstrate how the Market Scenario affects Model results, the price scenario reported in (Table 5) has been changed increasing the differential between Unleaded 95 RON and Unleaded Plus 98 RON of 20 €/m^3, while all the other constraints have been left unchanged.

Intermediate components quantities are fixed (assuming a *Plant Driven Approach*), thus we intend to analyse how the change of price differential affects the optimal management of blending components.

Product formulation resulting from the two cases is reported in Table 6: while the production of Light and Heavy Naphtha, and the total production of Gasoline remain unchanged, the percentile production of Unleaded PLUS 98 over Gasoline is almost doubled (from 8 to 16 %) and the average formulation of both products changes.

CASE A - LOW DIFFERENTIAL							
INTERMEDIATES (ton)				FINISHED PRODUCTS (ton)			
	INIT.STOCK	FIN.STOCK	INPUTS	H. NAPHTHA	L. NAPHTHA	UNLEADED 95	UNLEADED PLUS 98
PRODUCT TANK BOTTOM			7208.5	669.1	139.2	5721.4	678.9
BU (Butane)			327.7	0		321.1	6.6
DH (DIH Btm)	399.5		519.7	392.3		127.3	
HN (H.Naphtha)	2116.3	740.5	1843.5	1843.5		0	
MT (MTBE)	951.9		951.9	0		771.9	180
IS (Isom)	2491	2259.8	2070.5	0		2020.7	49.8
LN (L.Naphtha)	1522.8		2272.5	0	2272.5	0	
RI (R98+iC5)	3527.5	1780.7	6861.9	0		6469.3	392.5
MN (M.Naphtha)	2250.6		3079.2	2885.6	193.6	0	
TOTAL				5790.5	2605.3	**15431.7**	**1307.8**
BLENDED IN PERIOD				5121.4	2466.1	9710.3	628.9

CASE B - HIGH DIFFERENTIAL							
INTERMEDIATES (ton)				FINISHED PRODUCTS (ton)			
	INIT.STOCK	FIN.STOCK	INPUTS	H. NAPHTHA	L. NAPHTHA	UNLEADED 95	UNLEADED PLUS 98
PRODUCT TANK BOTTOM			7208.5	669.1	139.2	5721.4	678.9
BU (Butane)			288.2	0		226.5	61.7
DH (DIH Btm)	399.5		519.7	392.3		127.4	
HN (H.Naphtha)	2116.3	740.5	1843.5	1843.5		0	
MT (MTBE)	951.9		1084.4	0		710.8	373.5
IS (Isom)	2491	2609.6	1720.7	0		1698.4	22.4
LN (L.Naphtha)	1522.8		2272.5	0	2272.5	0	
RI (R98+iC5)	3527.5	1780.7	6861.9	0		5283.1	1578.8
MN (M.Naphtha)	2250.6		3079.2	2885.6	193.6	0	
TOTAL				5790.5	2605.3	**13767.6**	**2715.3**
BLENDED IN PERIOD				5121.4	2466.1	8046.2	2036.4

Table 6 - Impact of Price differential on Model Result

CONCLUSIONS

OTTMIX is an LP/MIP driven application dedicated to the optimisation of Batch Blending Operation on a Multi Periodic Base; a Model aimed to support the definition of the weekly schedule of Gasoline Blending Operation has been presented.

The application disposes of an intuitive interface oriented to the mentality of the Blending Operator, and can be easily managed even without a specific Mathematical Background.

Expected advantages are:

- progressive reduction of quality give away,
- reduction of laboratory tests needed to monitor batch quality,
- better management of intermediate components (eventually preserved for future productions),
- improvement of high value products yields from the same quantities of intermediate products,
- reduced investment cost against other well established technologies aimed to obtain similar results.