Drilling and Completion Material Management Improvement by Stochastic Modelling

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Abstract

The understanding of logistic phenomena entails a broad field of variables that relate to a wider set of considerations. There is a trade-off between general logistic models and mixed models. The former tends to underfit the real case scenarios, while the latter have to be carefully designed in order to have a clear managerial process. In this paper, it is considered a situation observed in a remote production field in Colombian East flatlands, Rubiales. In this case, the supply of materials had challenges in delivery opportunity, inventory rotation and forecast. Within this paper, we expose the data analysis process needed to construct a stochastic model to resolve those issues. Using the historical information available from the first stages of development in this Field some similarities could be noted and lead to a full evaluation which ended in a full forecast model that reduced material costs in 8,65% (approx.1.75 MUSD in first semester of 2019).

Keywords

Logistics, Forecast, stochastic model, material management

1. General considerations

Stochastic modelling was applied in many fields, including the topic of inventory management. We highlight applications in surgical supplies [1, 2], oil and gas [3], presciptive analytics [2], blood supply chain [4], maintenance [5],service facilities [6] and production [7] among others.

1.1. Stochastic logistic model

According to [8] stochastic logistic models are analogous to birth-death Markov process and has been extensively used for modelling randomness in biology [9, 10]. In this case, restricted probabilities of a factor increase and decrease, respectively, in an infinitesimal time interval are given by:

$$P\{\mathbf{x}(t+dt) = x+1 \mid \mathbf{x}(t) = x\} = \begin{cases} \eta(x)dt, & \forall x \leq U \\ 0, & \text{otherwise} \end{cases}$$
$$\mathbf{P}\{\mathbf{x}(t+dt) = x-1 \mid \mathbf{x}(t) = x\} = \chi(x)dt$$

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where $\mathbf{x}(t) \in \mathbb{N}$ represents the population size at time t

$$\eta(x) := a_1 x - b_1 x^2 > 0, \quad \chi(x) := a_2 x + b_2 x^2 > 0, \quad \forall x \in (0, U)$$

and

$$U := a_1/b_1 \in \mathbb{N}, \quad a_1 > 0, a_2 > 0, b_1 > 0, b_2 \geq 0$$

We propose a variation of this model for deterministic stochastic modelling. See section 3.

1.2. Type well

The considered Field, from now Rubiales, is a remote field in Colombian East Flatlands. The nearest urban area (7705 inhabitants approx.) is located a hundred kilometers away and does not count with industrial facilities that could provide the amount of material required by the drilling and completion development plans. Rubiales has a development plan that covers nine years with near a thousand wells distributed almost symmetrically in time, additionally, the geostructure holding the production formation is quite isotropic and regular through the area which allows considering a unique type well for almost all considerations related to engineering, design and supply plans. This consideration was accepted during the first two years of operation until some surplus materials began to grow into the inventory in the second semester of 2017.

The main constrain in designing the supply chain of Rubiales was its remoteness. Furthermore in this paper, we focus primarily on the tubular material required by the drilling and completion plans, primarily because in ECOPETROL, the operator company, there is different acquisition models for construction and consumable materials. For consumables the model is consignation and only the used material gets paid, but construction material was delivered in the warehouse and got paid once confirmed as received, thus, the cost of the construction materials that would not be used during the campaign will indeed be charged to the project. Although a well uses several construction materials different from tubular material, the quantity is unitary, it means that a unit of each material is used per well, so in that case, it was not necessary a forecast to adjust the quantity in order to avoid surplus and therefore related costs.

As seen in Figure 1 there are 6 types of tubular materials used in the well construction, those materials vary in length and weight therefore their quantities would be considered in tons instead of the usual length field units. For the specific quantities refer to Table 1.

2. Initial material quantity definition

We start by discussing the schedule of operations documented in the well construction chronograms, as they are the main guides for the drilling and completion operations. For the development plan in Rubiales, there was a main assumption that guided the organization of the activities of the project: each well has the same drilling and completion time no matter which rig is assigned to. Figure 2 shows a typical well construction chronogram for Rubiales in a 6-month period. It could be noted that there are several rigs working at the same time and that are short time periods between wells called mobilizations that correspond to the time that the rig uses to move from well to well and from well location to well location, this particularity

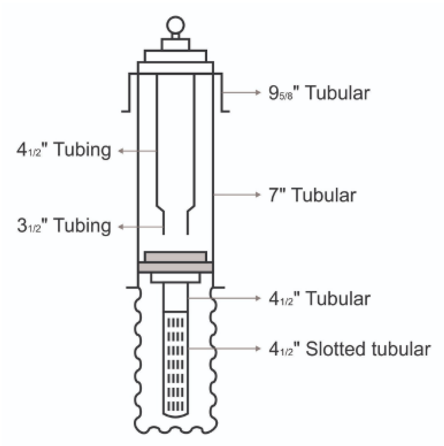

Figure 1: Type Well for Rubiales, dose not consider navigational design

Table 1
Tubular material quantities required by type well

Tubular	Quantity (ton)
9 5/8"	9.14
7"	40.06
4 1/2"	2.10
4 1/2" Slotted	5.26
4 1/2" Tubing	15.36
3 1/2"	0.67

will cause that the full analysis could not be a time-dependent one, this is resolved by using a stochastic approximation based in the same assumption.

Considering the former plan documents (Type well design and Well construction chronogram) it is possible to make a crude forecast by simply operating quantity of materials by the number of wells (seventy-one) in the considered time period (Table 2). This approximation could lead to a good estimate of the total of required material, but it does not consider any of the conditions required by the supply chain. At this point we need to evaluate commercial conditions for the acquisition of these materials, as per usual any stored material must be checked and maintained. More importantly, a warranty period covers the first six months after warehouse material reception, and once this period is over any of the possible fabrication issues could not be resolved through contractual means. Additionally, the material could suffer a degradation caused by the storage conditions. Therefore, a high inventory rotation is preferred, thus the possibility of receiving the whole quantity exposed in table 2 at once is not acceptable, the deliveries must be thoroughly planned.

It is possible to construct a planned consumption curve and note stabilized slopes that could be understood as consumption behavior (consumption rate), two ways of presenting this infor-

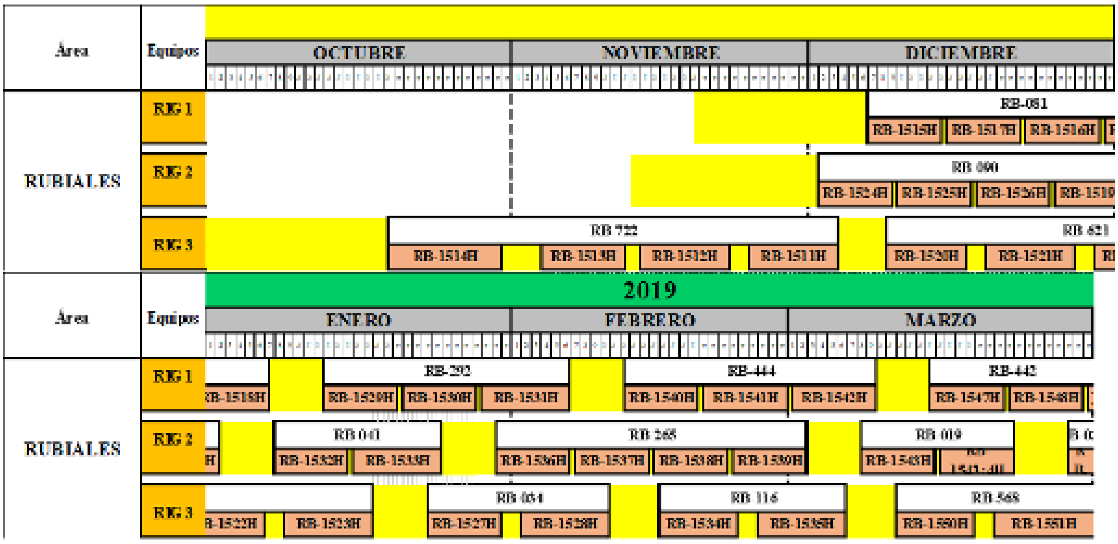

Figure 2: Typical well construction chronogram for Rubiales

Table 2
Initial Forecast.

Tubular	Quantity (ton)	Total (Ton)
9 5/8”	9.14	649.25
7”	40.06	2844.35
4 1/2"	2.10	149.43
4 1/2" Slotted	5.26	373.58
4 1/2" Tubing	15.36	1090.85
3 1/2"	0.67	47.92

mation could be used, time-dependent or time-independent, both have important applications for the model (Figure 4). On the time-dependent curve, we could observe a kind of regular slope which becomes clearer on the time-independent curve (see section 3.1) proving that the amount of material considered is constant for each well since the slope shows no variation. This behavior is, of course, an ideal one, the real behavior differs significantly and that’s why a further revision of forecasting is necessary.

In Figure 5 is shown the real delivery of 9 5/8” tubulars, the delivery does not seem to follow a regular pattern. Overlapping Figure 3 and Figure 5 it is evident that there is little correspondence between them (Figure 6). An overlap of Figure 5 with the time-dependent curve shown in Figure 4 leads to the initial system state graphic (Figure 7). In it we could the horizontal distance between the real delivery curve and the consumption curve corresponds to the material storage time before use, in other words, it represents the inventory rotation; the largest the distance between the curves, the longest the storage period, and equivalently, risks associated

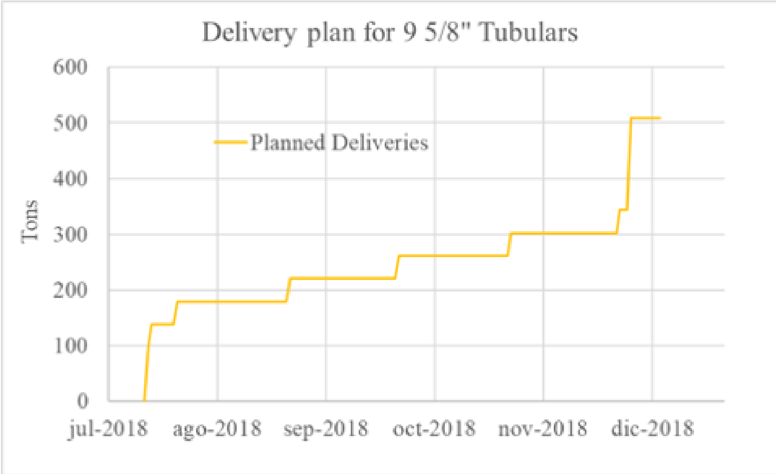

Figure 3: Delivery plan for 9 5/8” tubulars

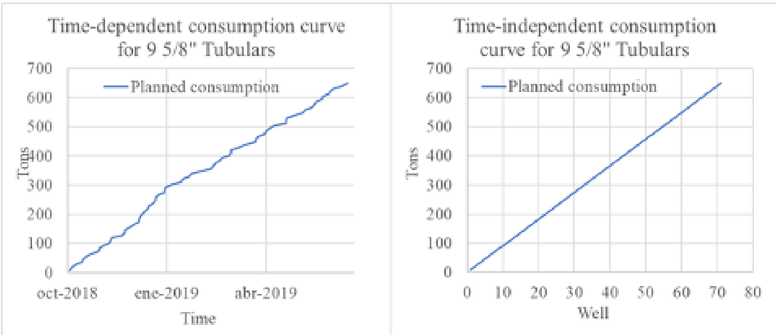

Figure 4: Time-dependent and time-independent consumption curves

to material miss storage and wrongful handling grows.

3. Consumption rate and proposed model

The consumption rate could be defined as the speed at which the material is consumed. Since the operation time is not constant due to the mobilization between wells or well locations, it is necessary to define an arbitrary independent variable to observe this behavior, so the consumption rate was established as ton/well. Furthermore, since wells were deployed sequentially the well number can be used as an arbitrary time variable, thus allowing to create a comparison graph between planned consumption and real consumption (Figure 8) that shows the divergence between planned and real consumption rates. Hereby those rates seem to have a constant slope, an expected trend for the planned consumption rate, since the quantities follow the initial estimation. zooming on the real consumption curve (Figure 9) the slope shows a variation from well to well showing that the real consumption is not constant.

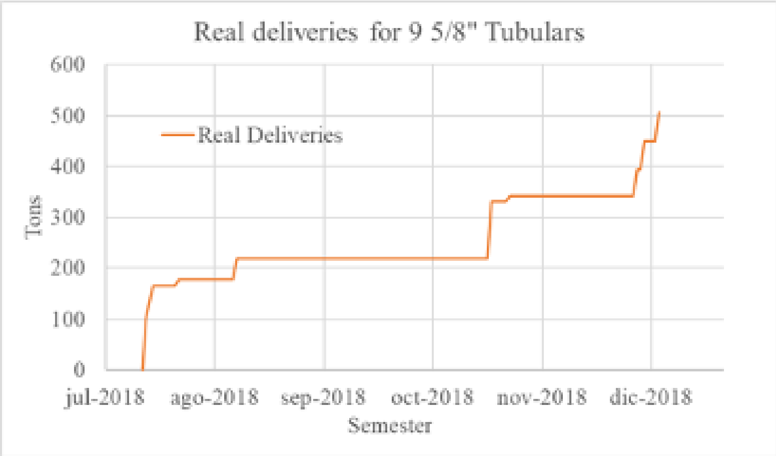

Figure 5: Real delivery material curve

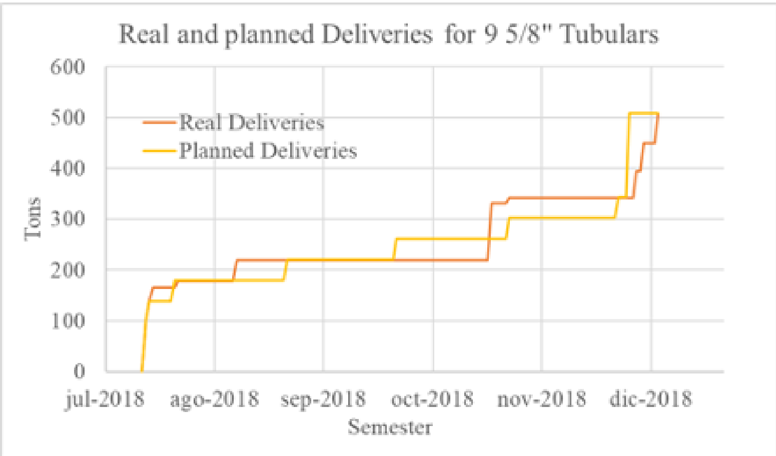

Figure 6: Overlap real and planned delivery material curves

Since the expected consumption rate is defined from plan documents the plot of planned consumption slope will be a constant equal to the average consumption per well. If the real consumption well to well is operated to seek the historic average a behavior emerges showing an asymptotic tendency to the real consumption average.

$$CP_i = \sum_{i=1}^{n} Ci/n \tag{1}$$

CP_i stands for the consumption average in the well i and C_i stands for the consumption in the well i.

Next, based in the theorem in [11] we propose for our deterministic model:

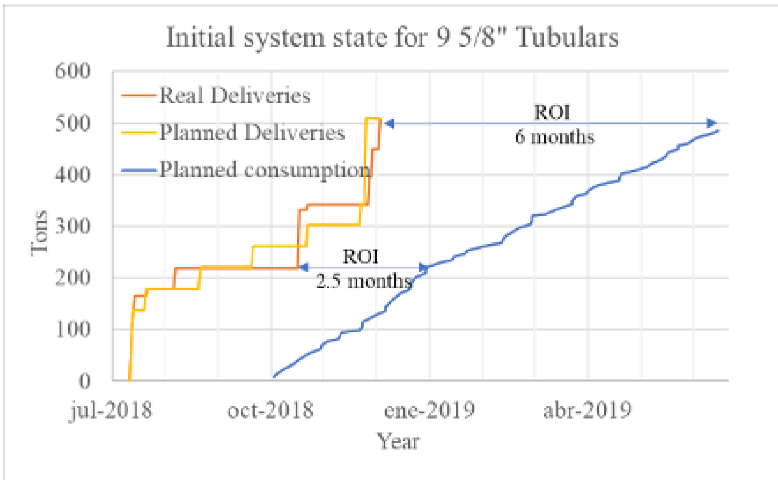

Figure 7: Initial system state graphic

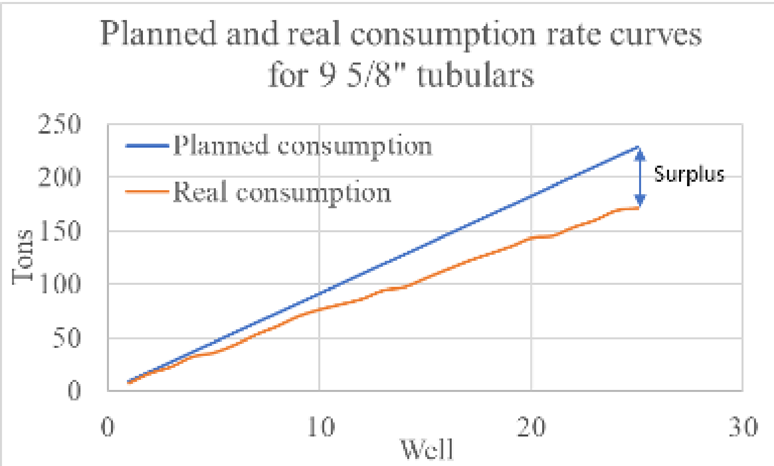

Figure 8: Planned and real consumption rate curves for 9 5/8" tubulars

$$VCP_i = \left[\frac{((CP_i - CP_{t-1}))}{2} \right]_i \tag{2}$$

VCP_i stands for the derivative in consumption average in instant (well) i ,CP_i stands for the consumption average in the well i , $CP_i - 1$ stands for the consumption average in the well $i - 1$.

Applying equations 1 and 2 a plot for average planned consumption and real average consumption could be constructed (Figure 10) and finally noted the real divergence in the consumption and therefore the surplus material that had been purchased for the whole project which leads to a reevaluation in the plan documents to reduce the initial quantities to more realistic quantities. Figure 11 shows the final state of the system once this model was applied and shows the reduction in the acquisition, the use of the previous storage material and the

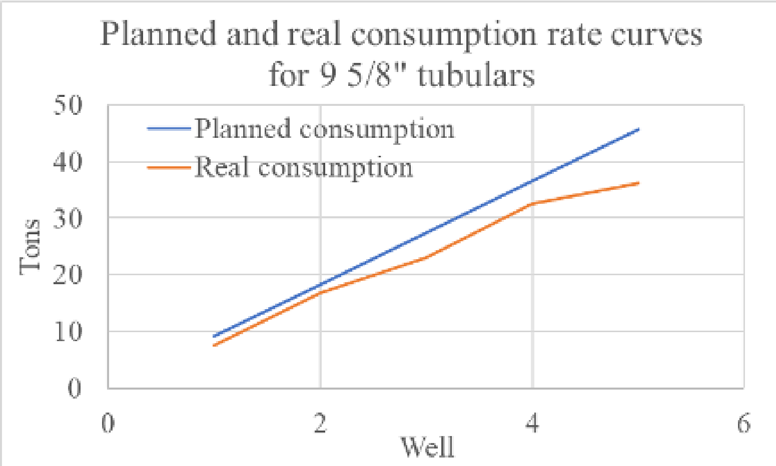

Figure 9: Real consumption rate curve – first five wells

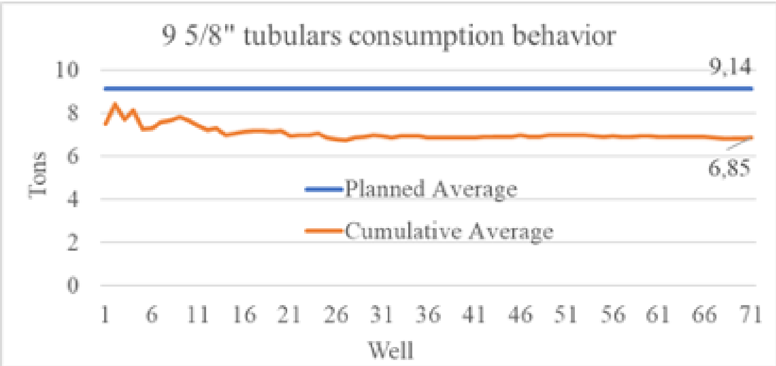

Figure 10: 9 5/8" tubular consumption behavior curve

adjusted inventory rotation.

4. Results

Once the model was applied it was verified in the next 66 wells. Figure 12 shows the final consumption behavior versus the initially planned consumption and the stabilization in the slope for the model reveals a significant divergence between planned and real consumption. Table 3 summarizes the total differences in each material category which could lead to a buy surplus of 414.56 tons of material. In Figure 12, 7" tubulars show abnormal behavior due to operational troubles occurred in wells 58,59 and 64 where consumption rises above any previous consideration, but the model absorbs the change and return to a regular value once the normal operation is reached again.

For the next wells the new stabilization average will be used plus some contingency value based on normal assurance company policies. This will have a total potential effect over approx.

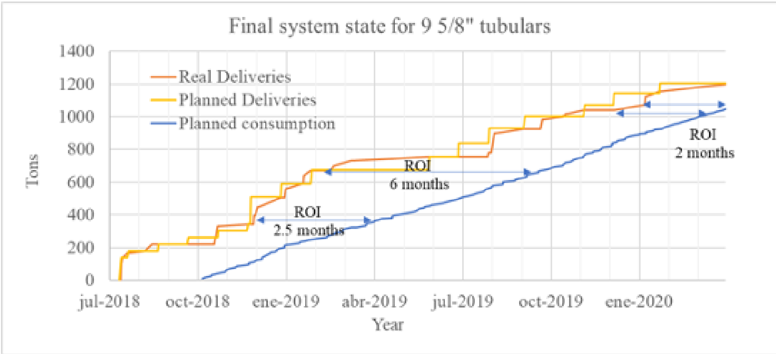

Figure 11: Final system state for 9 5/8” tubulars

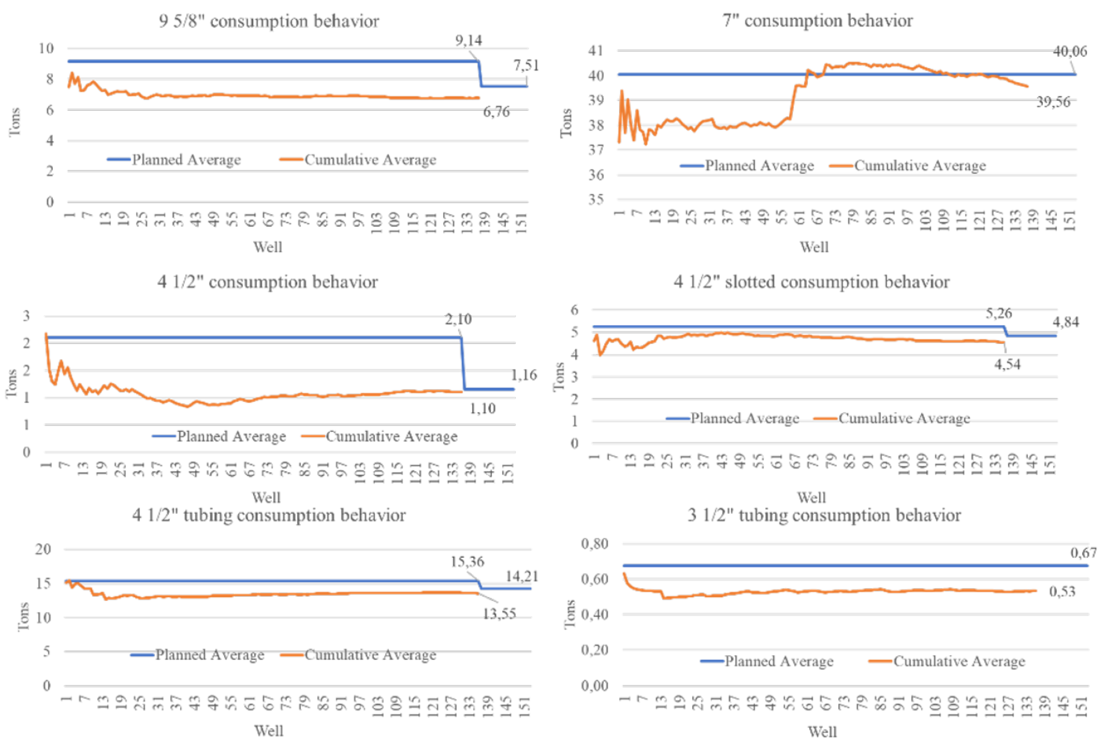

Figure 12: Consumption behavior curves

750 wells to develop until 2027.

Figure 13 shows the final system state. Three situations are observed:

- For 9 5/8”, 7” and 4 1/2” slotted materials, the system reaches a stabilization with an inventory rotation around 3 months which match with the general commercial considerations.
- For 4 1/2” and 3 1/2” materials it was necessary to suspend any acquisition be-cause the

Table 3
Material Reduction for 82 wells

Tubular	Planned (Ton)	Real (Ton)	Difference (Ton)
9 5/8”	603,53	452,1	151,43
7”	2644,05	2617,56	26,49
4 1/2"	138,91	71,94	66,97
4 1/2" Slotted	343,27	300,96	46,31
4 1/2" Tubing	1014,03	898,92	115,11
3 1/2"	44,55	36,3	8,25
Total	4792,34	4377,78	414,56

surplus obtained during the information capture phase and previous campaigns fulfilled the actual campaign, in this case, the added value was not to continue storing material with a possible lack of future use.

- For 4 1/2” tubing, a stabilization in inventory rotation was reached but a change in the acquisition policies required to buy additional material in order to avoid stoking out during the campaign execution, nonetheless the consumption model reached its stabilized phase.

In conclusion, the model application for 66 wells reported a substantial reduction in the planned requirements of material in about 8.65%, representing a total cost reduction of 1.35 million USD dollars, and a reduction in risks and costs associated to the storing of 414 tons of surplus material that could be estimated in 0,4 million US Dollars. Considering that about 750 wells are still in process of construction in Rubiales the impact of the model could represent a huge improvement in material management for Ecopetrol in the next seven years.

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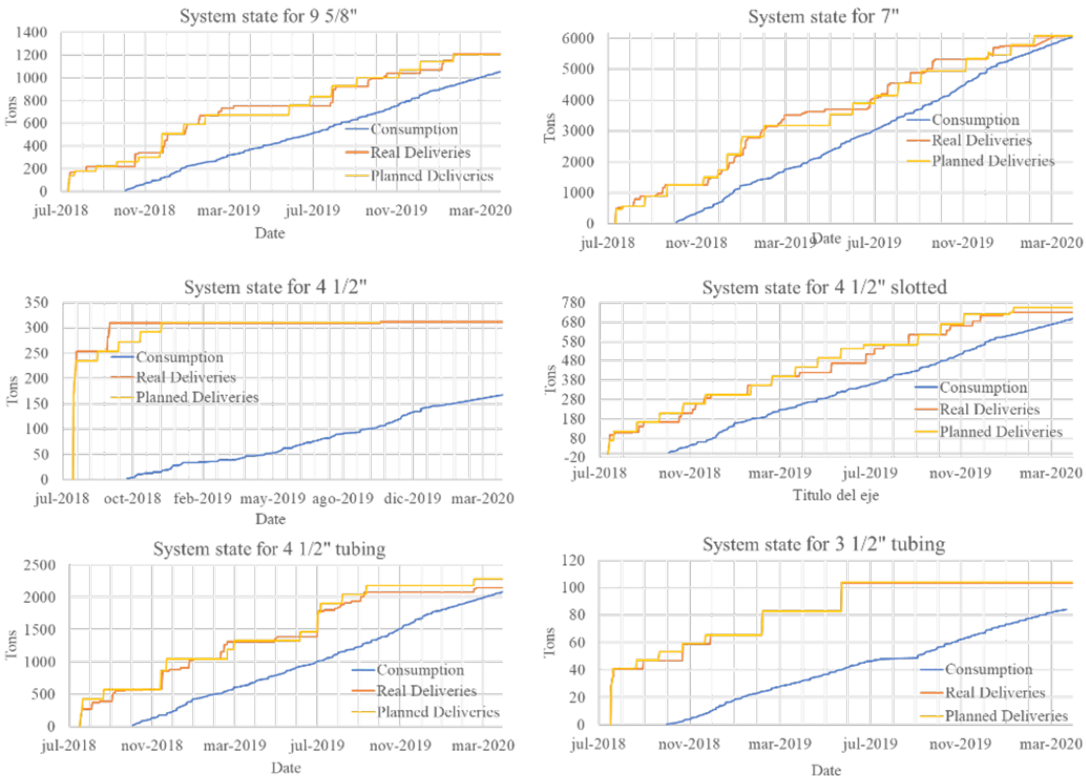

Figure 13: Final system state

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