

# TYRE DURABILITY OF TRACTOR UNITS USING REMOLDING AND RETREADING TECHNOLOGIES



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## ABSTRACT

This paper has been the product of the investigation and application of the results of more than 5 years in the use of tyres of international brand tractor units representing the vehicles which are the subject matter of this paper. Tractor units support a weight ranging from 40 and 50 tones; for this reason, their tyres must have a resistance that guaranties the completion of their useful life.

The tyres of these vehicles may suffer big deformations but their shape may be recovered once the effort producing the deformation disappears. This characteristic allows them to exploit all its potential and fully extend their useful life period. This can be achieved through the application of tyre remolding and retreading technologies, widely used processes in the industry in most parts of the world, as the most profitable manner to extend the useful life period of tyres.

In Cuba, there is a general culture on the use of tyre retreading technology, but not on the use of remolding technology, being it a feasible way that could provide greater savings in the economy and could guaranty the solution to big needs in production and services.

**KEYWORDS:** tyre, durability, remolding, retreading.

## SUBJECT RATIONALE:

Tyres used in tractor units, which are the subject matter of this paper, did not use to be recovered but they were just discarded after completion of their first life cycle. An analysis was performed with the purpose of increasing their durability, by applying tyre remolding and retreading technologies, in order to increase the kilometer performance and extend their useful life stages, and thereby, reduce costs associated to the purchase of new tyres, since by applying remolding and, subsequently, retreading, the tyre can achieve a potential in performance, with a significantly lower cost, which will

ultimately have an impact on the economy. The work is structured in the following manner: firstly, there is a brief characterization of the Logistic Operations Department (DOL, for its Spanish acronym) of the company *Empresa de Telecomunicaciones de Cuba S.A* (ETECSA, for its Spanish acronym), which consists in the characterization of the vehicles, which are under study and their tyres, with a diagnosis of the tyres used on the vehicles of the Department. Subsequently, an analysis on the wear and tear of tyres was performed, through a study of their influencing parameters (such as inflation pressure, tyre load, tyre rotation, main tyre failures during its use); also, a characterization of the roads throughout which these vehicles travel was made. Then, a study on the Technologies that may influence on the life expectation of tyres was conducted, by posing the technical basis of the remolding technology, the general recommendations for its application and the specific regulations established for this process and their characteristics.

The analysis of the retreading technology, its importance and the retreading methods according to the analyzed tyres was conducted.

## I. CHARACTERIZATION OF VEHICLES AND TYRES ANALYZED

### 1.1 CHARACTERIZATION OF VEHICLES ANALYZED

For the conduction of this work, the vehicles that guaranty the transport of the main elements of the Logistic Operations Department of the company *Empresa de Telecomunicaciones de Cuba* were analyzed. Such vehicles comprise international brand tractor units, 94500 model, coupled to trailers with a load capacity ranging from 40 and 50 tones, which manufacturing year is 1996. Characteristics:

Type of vehicle		Tractor unit
Brand		International
Net weight	(kg)	26,844
Trailer capacity	(tones)	50
Motor type		Detroit
Country		U.S.A
Maximum power	(W) or (CV)	(272135 / 316265) or (370 / 430)
Tyre type		1100 R 22.5 (remolding)
Year of manufacturing		1996

### 1.2 CHARACTERIZATION OF TYRES OF THE TRACTOR UNITS ANALYZED

The tyres of brands Maxxis from Taiwan, Bridgeston from Thailand and Jet Way-JUH from Korea were analyzed. Their dimension is 11.0 R 22.5 radial type, remoldable in the 3 cases, representing 67.9%, 10.7 % and 21.4 %, respectively, of the tyre market for the transport basis selected; distribution shown in graphic N° 1. (Exhibit N°1)

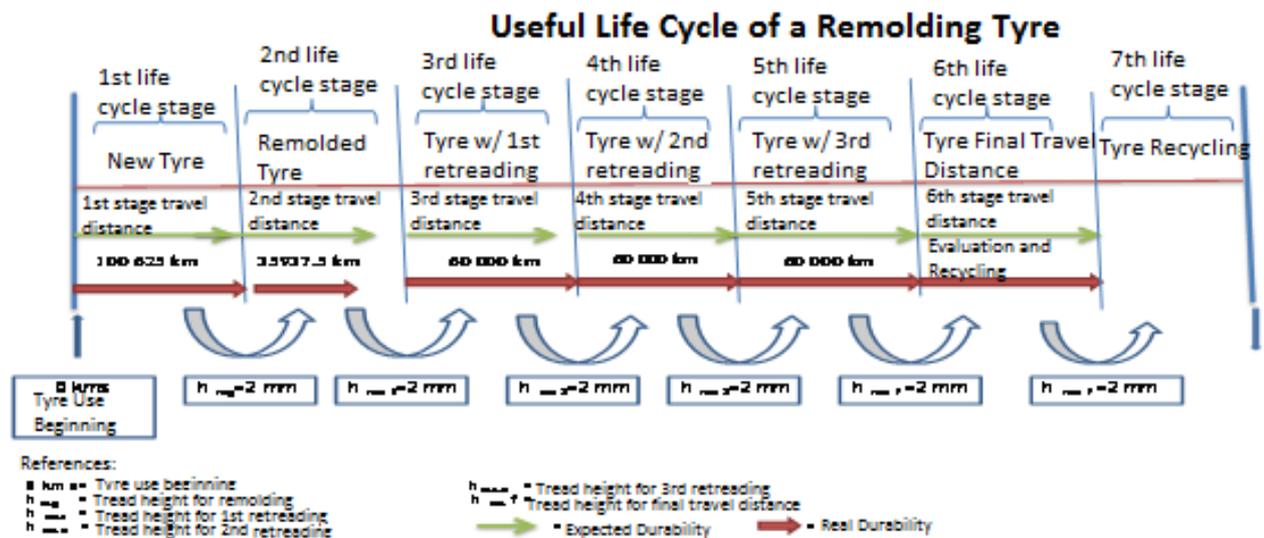
<b>Manufacturer (Brand)</b>	<b>Maxxis</b>	<b>Bridgestone</b>	<b>Jet Way-JUH</b>
<b>Tyre width (mm)</b>	<b>1100</b>	<b>1100</b>	<b>1100</b>
<b>Interior diameter (inches)</b>	<b>22.5</b>	<b>22.5</b>	<b>22.5</b>
<b>Of radial construction</b>	<b>R</b>	<b>R</b>	<b>R</b>
<b>Designed for remolding</b>	<b>Remolding</b>	<b>Remolding</b>	<b>Remolding</b>

Speed symbol (Km/h)	L (120)	G (90)	M (130)
Load capacity in simple assembly (Kg. /lb.)	3150/6946	2800/6175	3150/6930
Load capacity in double assembly (Kg. /lb.)	2900/6395	2650/5840	2900/6380
Inflation pressure in simple assembly (kpa/Psi)	850/123	720/105	350/125
Inflation pressure in double assembly (kpa/Psi)	850/123	720/105	350/125
Tyre without tube	TUBELESS	TUBELESS	TUBELESS
Country of origin.	Taiwan	Thailand	Korea

## II. DETERMINATION OF THE TYRE LIFE CYCLE

### 2.1 TYRE LIFE CYCLE

The tyre life cycle of a freight vehicle was determined, which relates to the period covered from its date of installation on the vehicle until the moment of its withdrawal from usage is determined, once the resources allowing the vehicle to move with the necessary safety and comfort have been exhausted. The analysis of the life cycle of the tyre type used by these tractor units shown in graphic N° 2 states that a proportional relation to the application of remolding and retreading technologies is maintained, and that through them, the tyre reaches up to its sixth life stage, thus exploiting all its potential and, ultimately, obtaining an economic benefit. (Graphic N° 2).



Graphic N° 2 Life stages of a remolding tyre. (Graphic provided by the authors)

Graphic N° 2 shows the 7 stages of the life cycle that a remolding tyre of a freight vehicle may achieve, taking advantage of the application of remolding and retreading technologies. Table N° 1 shows the tyre life cycle stages, specifying the aspects to be considered from its beginning to its completion. (Exhibit N°3)

## 2.2 TYRE WEAR AND TEAR

The wear and tear of the tyre was determined on the basis of influencing factors such as inflation pressure, load, road conditions (2, 3, 13) and non-rotation of the tyre (6, 8, 13). In each case, partial conclusions were reached, thus determining that the behavior of the 112 tyres 11.00 R 22.5 in use provided the results shown in graphic N° 3 (Exhibit N° 2).

Graphic N° 3 shows the durability in kilometers reached by the tyres that were removed for having a tread of 2 (mm) high, and which were worn out by natural wear tear.

Size	Causes	Amount (u)	%	Price (\$)	Wear and Tear (mm)	KM Performance (km/mm)	Durab (Km)	Cost/ 10,000 km	CPK (\$/km)
1100 R 22.5	Normal wear and tear	85	76	230.43	12.4	9,388.8	116,421	19.7	0.00197
	Tyre explosion	6	5	130.43	12.5	8,696.2	108,702	21.2	0.00212
	Tread crack	5	4	230.43	12.1	9,434.6	114,459	20.2	0.00202
	Irregular wear and tear	8	7	230.43	11.3	9,457.6	106,871	21.6	0.00216
	Flat tyre	4	4	230.43	12	9,121.2	109,454	21.0	0.00210
	Damage on sidewalls	4	4	230.43	9.9	10,976.3	108,665	21.20	0.00212
	Subtotal	27	24		11.56	9,537.18	109,570	21.03	0.00210
Total	112	100		11.98	9,463	112,996	20.4	0.00204	

**Table N° 2. Causes for tyres 1100 R 22.5 out of work in the tractor units studied**

As shown in table N° 2, of the 112 tyres which were gotten out of work for different causes, 85 of them were due to natural wear and tear, which represented a 76% of all the tyres which were gotten out of work in their first life stage.

## 2.2 CALCULATION OF SAMPLE SIZE

The "Methodology of the reliability experiment" was used for determining the sample size, by using the Statgraphic program consulted in (5)

The reasons why tyres 1100 R 22.5 of the analyzed units gotten out of work have been studied considering the durability values expressed in kilometers as the continuous randomized variable of the sample. These were passively collected through the technical documentation. An orderly list of 112 values covering from 90095 to 114626 was obtained; this represents the kilometer distance reached until the occurrence of the failure (Table N° 3), that is, until the moment in which the analyzed tyres got out of order.

90095	97641	98723	105708	111324	114589	115324	117365	117643	126888	136827	144626
90095	97641	102008	105708	111324	114589	115324	117365	117643	126888	136827	144626
90095	97641	102008	105708	111324	114589	115324	117365	123531	126888	136827	
90095	97641	102008	110373	113252	115263	115324	117365	123531	126888	136827	
90095	97641	102008	110373	113252	115263	115324	117643	123531	126888	136827	
90095	97641	105708	110373	114589	115263	115324	117643	123531	126888	136827	
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90095	98723	105708	110373	114589	115263	117365	117643	123531	136827	144626	
90095	98723	105708	110373	114589	115324	117365	117643	123531	136827	144626	

Table N° 3 Orderly list of 112 variables representing the kilometer distance reached until the occurrence of the failure (out-of-order condition)

Through the conduction of the reliability experiment, the following results were obtained:

1. The value of the minimum sample was selected (3 vehicles)  
This was obtained from the ratio

$$n_{\text{teo min}} = \frac{\ln(1-\alpha)}{\ln R(t)_{\text{min}}}$$

where:

$n_{\text{teo min}}$  → is the minimum amount of elements that the studied sample must contain.

$\alpha$  → is the significance level recommended for the calculation.

(0.70-0.98). A greater than  $\alpha$  → plus sample.

$R(t)_{\text{min}}$  → is the minimum admissible element probability of work without failure

$R(t)$  = 0.90-0.95 for elements guarantying safety.

$R(t)$  = 0.85-0.90 for the rest of the elements.

For this case:

$$\alpha = 0.95$$

$R(t)_{\text{min}} = 0.94$  → Because the tyre is an element guarantying safety in the vehicle.

$$n_{\text{teo min}} = \frac{\ln(1-\alpha)}{\ln R(t)_{\text{min}}} = \frac{\ln(1-0.85)}{\ln 0.95}$$

$$n_{\text{teo min}} = \frac{\ln 0.05}{\ln 0.94} = -2.99573 / -0.06187 = 48.4 \approx 48 \text{ tyres}$$

Since each vehicle has 10 tyres, 5 vehicles were selected to conduct the study. The respective measurements to each tyre were made.

2. Passive data collection was performed through the documentation of the vehicle files and technical reports.
3. The randomized variables of the failure were ordered. (112)
4. The abnormal values were cleaned off.
5. The resulting values represent the values of kilometers traveled until the tyres 1100 R 22.5 of the selected tractor units gotten out of work. (Table N°3)
6. The amount of intervals for the statistical series was determined.
7. The interval width was established.
8. The tubular representation was developed.
9. The reliability interval was determined.

The values of all these parameters appear in the following chart:

PARAMETERS	VALUE
Sample number	112
sample size	48 tyres
Mathematical expectation	114699.0
Variability	2.02919E8
Standard deviation	14245.0
Standard error	1346.02
Minimum value of continuous randomized variable	90095.0
Maximum value of continuous randomized variable	144626.0
Range	54531
Variation ratio	12.4195 %
Reliability interval	$112031.0 \leq 114699.0 \leq 117366.0$ km

The tyre control system was determined by establishing the scheme of all the activities that must be conducted during the use of the vehicle with its corresponding kilometer distance, as shown in graphic N° 4 (Exhibit N° 4).

The control and maintenance system was adopted with the purpose of monitoring and detecting any abnormality that may arise in the tyre and reducing the possibility of not being remolded or retreaded, where H: tread height

As shown in graphic N° 4 (Exhibit N° 5), the proper amount of kilometers to do this was determined for each operation.

### III. TECHNOLOGIES FOR THE EXTENSION OF TYRE LIFE DURABILITY

Examples are provided on the basis of data derived from by the kilometers traveled by tyres taken as sample size, obtaining the result shown in graphic N° 2 (Theoretical system expected for the tyre use).

From here on, the equations which allow making the calculations of the Technical and Economic Indicators of Tyres of the Logistic Operations Department are obtained (Table N° 4, Exhibit N° 4).

Graphic N° 5 shows the real system for the tyre use provided by the authors of the work.

#### 3.1 REMOLDING PROCESS ANALYSIS

The possibility of applying the remolding process in the analyzed tyres was determined, in which case, there is a real possibility of tread groove deepening according to the original height and, a consequent reproduction of the worn tread pattern with the purpose of increasing the tyre durability. Some technical elements recommended by specialists in this activity were analyzed (1)

The technological process for remolding was established, considering the operations that must be conducted chronologically. On this basis, the following operations were established: (5),(13)

1. Inspecting tyre for remolding.
2. Measuring the tread depth around the entire tyre perimeter.
3. Taking the tread surface for remolding to a uniform dimension.
4. Selecting the blade shape to be used (round or angular).
5. Before placing the blade, be sure that the equipment is turned off.
6. Remolding a small area (approximately 150 mm.)
7. Removing the rubber previously cut.
8. Conducting the essential remolding operation.
9. Making sure that the tyre has been completely remolded without any damage on the cords.

### 3.2 RETREADING PROCESS ANALYSIS

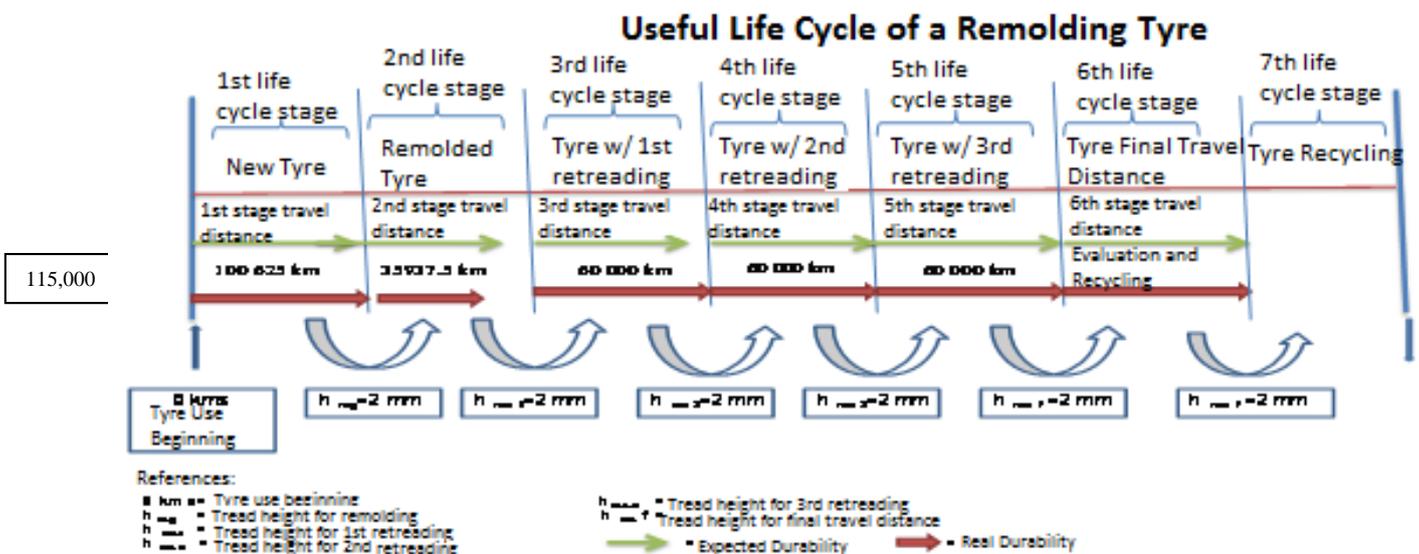
The retreading process was analyzed considering that, currently, this type of tyres can be subject to cold retreading process. (9), (11)

The first retread, as shown in graphic 5, is made once the tyre has reached the kilometer distance after the retread has been made and the tread height has again reached the 2 mm value.

The second retread, as shown in the same graphic, is made once the tyre has reached the intended kilometer distance after the first retread has been made and the tread height has reached the 2 mm value.

The third retread, as shown, is made once the tyre has reached the intended kilometer distance to be used after the second retread has been made.

In the case of the retread, the technological process applied in each case is the one prescribed by the technical regulations of the Ministry of Transport (9).



Graphic N° 5 Life cycle based on the real system of use of the analyzed tyres of tractor units under study.

As can be noted from graphic N° 5, by applying the remolding (2nd stage of the cycle), the tyre can travel 35,937 kilometers more. That is, until the end of the 2nd

stage, tyres can travel 136,562.5 km, which represents a 25.6 % increase as to the utilization of the tyre resources. (13)

As a summary of the analysis conducted, the following aspects are noted:

1. The lack of due attention during technical maintenance proceedings as to tyre-related tasks (rotation, balance, regulation of the steering system and brake system, revision of the suspension system), makes tyres be worn in a non-uniform manner, thus resulting in a greater wear and tear.
2. Developing a simple system of equations for obtaining different values for remolding and retreading processes in second and third life cycle, is an important step for its subsequent application in any entity.
3. The characterization of the type of ground, as well as the application of the different programs for ordering the reasons why tyres got out of work and controlling tyres in vehicles is a progression step towards the control of these elements.
4. The capacity of extending the useful life of tyres as from the remolding and retreading processes gives the possibility of not having to store or expose them to outdoor conditions, which prevents damage to the environment.

The economic analysis of the proposed project was developed, thereby reaching the results presented in the following Table N° 1.

**Table N° 1. Cost behavior per kilometer**

Cost per kilometer (\$/Km)	Expected (Km.)	Real (Km.)	Price (\$)	CPK Expected	CPK Real
New tyre	130,000	115,000	230	0.0018	0.0020
Remolded tyre	56,875	50,312.5	50	0.0009	0.0010
First time-retreaded tyre	162,500	143,750	139	0.0009	0.0010
Second time-retreaded tyre	292,500	258,750	139	0.0005	0.0005
<b>Applying all the stages</b>	<b>422,500</b>	<b>373,750</b>	<b>558</b>	<b>0.0013</b>	<b>0.0015</b>

The saving represented by the inclusion of remolding and retreading was determined, as well as the conduction of tasks included in the programmed technical maintenance proceedings.

#### **IV WORK CONCLUSIONS**

The work developed has allowed reaching the following conclusions:

- 1) It is possible to apply the remolding and retreading technologies to tyres of the DOL of ETECSA to increase their durability.
- 2) The 21.19% of the road conditions throughout which the studied vehicles traveled are evaluated as bad or regular, therefore, their influence on the tyre wear and tear increases.
- 3) By applying the remolding and retreading processes, the tyre kilometer distance

Increases, **258,750 Km**. This represents a **225%** increase in durability in relation to a new tyre, for which **2.25** additional tyres are obtained, only with the benefits achieved.

- 4) The economic benefit contributed to the DOL of ETECSA with the application of remolding and retreading technologies is \$ 189.50 per tyre.  
By applying remolding and retreading processes there is a saving for the concept of non-acquisition of new tyres of 74.6%.

#### **IV. Literature references used**

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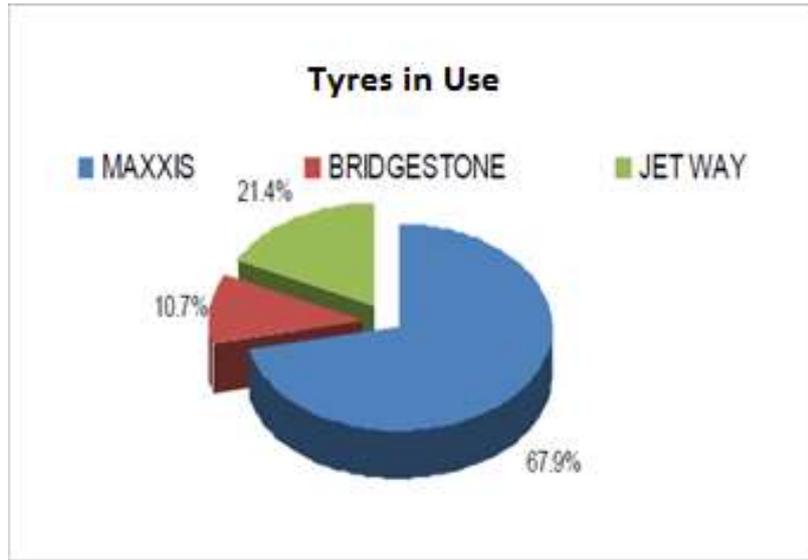
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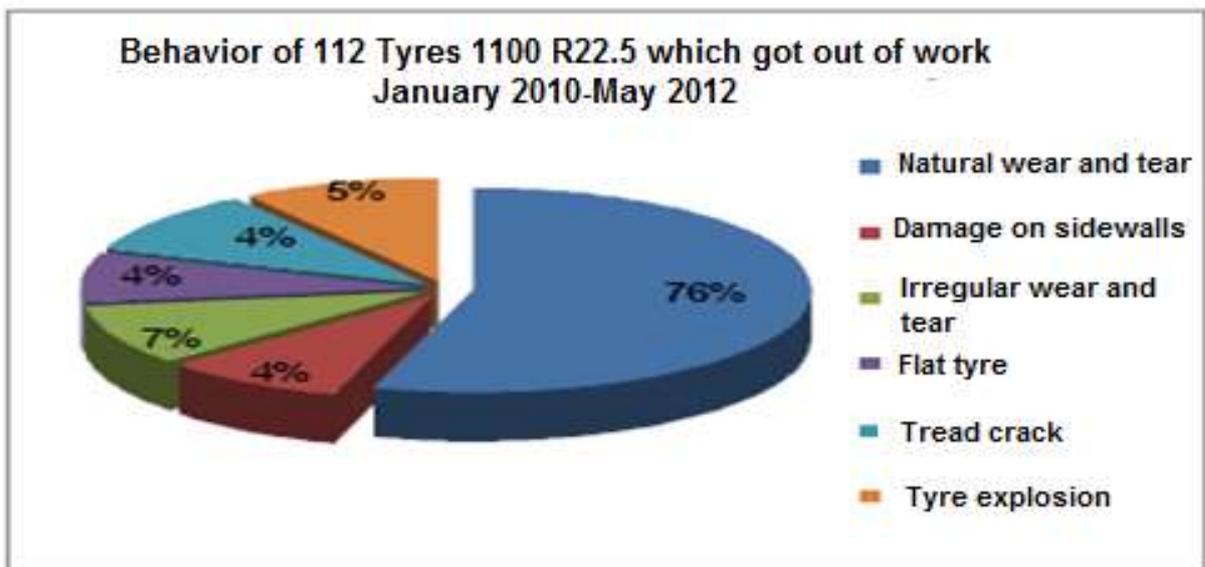
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Exhibit N°1



Graphic N° 1 Distribution in % of the most used tyres in tractor units analyzed (provided by the authors)

Exhibit N°2



Graphic N° 3 Percentage distribution of the 112 which were gotten out of work in 2, 5 years of transport basis work. (Taken from (13) page 28)

Exhibit N°3

N°	LIFE CYCLE STAGES	STAGE BEGINNING	STAGE CONCLUSION
1	1st stage	Installation of new tyre	Tyre removal for remolding ( $h_{br}=2$ mm)
2	2nd stage	Remolded tyre	Tyre removal for first retreading ( $h_{br}=2$ mm)

3	3rd stage	Retreaded tyre with first retreading	Tyre removal for second retreading ( $h_{br}=2$ mm)
4	4th stage	Retreaded tyre with second retreading	Tyre removal for third retreading ( $h_{br}=2$ mm)
5	5th stage	Retreaded tyre with third retreading	Tyre removal for evaluation and diagnosis ( $h_{br}=2$ mm)
6	6th stage	Tyre evaluation through diagnosis of technical state	Final travel distance according to its technical state
7	7th stage	Tyre recycling	Passing to new ways of usage

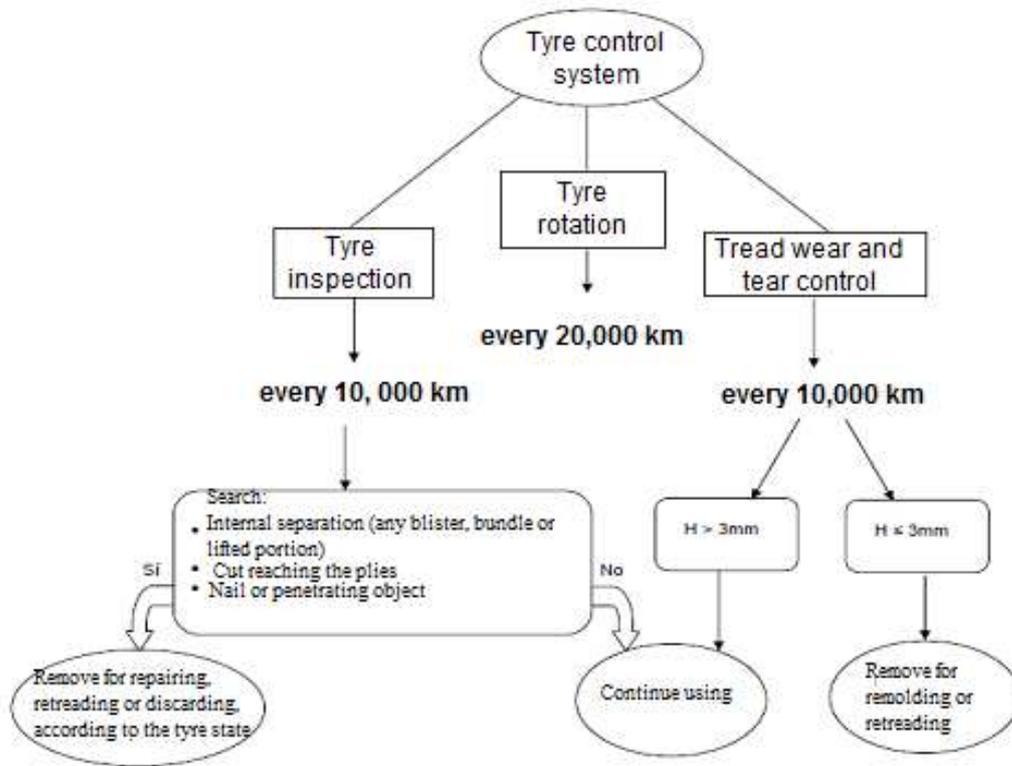
Table N° 1 Life cycle stages of tyres on freight vehicles  
(Table provided by the authors)

#### Exhibit N°4

CATEGORY	EQUATION	RESULT
RK: Kilometer performance (km/mm)	$RK = km/H \quad H=16$ mm	7,187.5 ( km/mm)
Kmreg: proper kilometer distance for Remolding	$Km_{reg} = RK * H = 14$ mm	100625 (km)
Areg: kilometers provided by the Remolding	$A_{reg} = RK * H = 5$ mm	35937.5 (km)
Km rec <sup>1</sup> : proper kilometer distance for 1st cold Retreading	$Km_{rec1} = Km_{reg} + A_{reg}$	136562.5 (km)
Km rec <sup>2</sup> : proper kilometer distance for 2nd cold Retreading	$Km_{rec2} = Km_{rec1} + Nb$	196562.5 (km)
Km rec <sup>3</sup> : proper kilometer distance for 3rd cold Retreading	$Km_{rec3} = Km_{rec2} + Nb$	256562.5 (km)
Km rec total: kilometer distance provided by the 3rd retreading	$A_{rec3} = Km_{rec3} + Nb$	316562.5 (km)
Total Tyre Durability	$D_T = Km_{reg} + A_{reg} + 3 * rec_{12}$	316562.5 (km)

Table N° 4 Equations that allow calculation of Technical and Economic Indicators of Tyres (equations determined by the authors in (13))

### Exhibit N°5



Graphic N° 4. Tyre control system (Graphic provided by the authors)