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## **CAPITAL RISKS AND RATES OF RETURN RELATED TO THE INVESTMENTS IN PAVEMENT**

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## **ABSTRACT**

This article presents a procedure on how to obtain financial information related to the capital invested in pavement. Such information includes the following items: 1) the rate of return of the capital invested in pavement; 2) the cost of the removal of investments in pavement, and 3) the risks associated with the investments in pavement. The nominal rate of return of the capital invested in pavement is calculated based on the pavement degradation rate. The main risks associated with the pavement subsystem are described and a plan of theoretical approach and quantification is proposed. Finally, based on the nominal rate of return and on the risks, the real rate of return of the capital invested in pavement is obtained, and some analysis performed during the planning of investments of the Road Concessionaire for the 2005/2006 term are presented. The whole procedure is based on the Pavement Management System of Consórcio Univias, which manages three Toll Road Concessionaires in the state of Rio Grande do Sul, Brazil, covering 1,027 km.

## **KEY WORDS**

Risks, investments, pavement, management

## **INTRODUCTION**

This work aims at: 1.) presenting a procedure to obtain the real rate of return of the capital invested in pavement and 2) presenting some theoretical concepts as well as a procedure for the calculation of the risks associated with the investment in pavements. In the meantime, it is important to highlight the fact that all the results obtained when applying this procedure, will only be trustworthy when the project takes into account the most relevant issues related to the roads master file, to the technological control (TC), to the quality control (QC) and to the forecast models of performance at the network as well as at the project. These steps are the basis for the consistence of the data used in the procedure herein proposed and they may be concentrated in a Pavement Management System (PMS), as the one used by Consórcio Univias. The cases, which are going to be presented, refer to real situations that were analyzed at the annual planning of the Concessionaire. The values referring to the annual investments are not real and are presented in terms of Monetary Units (MU).

## **NOMINAL RATE OF RETURN OF THE CAPITAL INVESTED IN PAVEMENT**

### **Simulation of investment scenarios**

In order to obtain the nominal rate  $ij$ , which returns the capital invested in the actual assets "Pavements",  $n$  pairs of investment scenarios are simulated through a Pavement Management System (PMS). These simulations consider a budget restriction during the first year and no restriction in the second year. These scenarios should generate, by the end of the analysis period, the same residual value so that a comparison basis is achieved. In case the residual values are different, they should be considered as a negative cost of the investment in the second year of each pair of financial scenarios simulated. The reason why many pairs of financial scenarios are simulated is to determine the decrease on the physical parameter of control in the second year of the analysis period, which has been originated by a decrease of investments during the first year (budget restriction). This parameter of control may be the PSI, the residual lifespan (RL), or any other, as long as this parameter has a strong correlation with the real physical condition of the roads. The investments  $I_k$ , made in the first year, can assume any value within the interval estimate  $(0, A)$ , where  $A$  is the minimum value accepted which keeps the target control parameter on the wished standard. In this way,  $A$  can be the minor investment to keep  $PSI = 3$ , for instance. Finally, there is an investment estimate needed in the second year, which will make it possible to recover the decrease observed on the physical parameter of control caused by the scenarios constrained by budget restrictions in the first year. Table 1 presents some scenarios generated by the PMS of Consórcio Univias in 2005 and 2006.

Table 1 - Scenarios simulated on the PMS of Consórcio Univias

<i>k</i>	2005		2006	
	<i>I</i> (MU x 10E6)	PSI	<i>L</i> (MU x 10E6)	PSI
5	31	3	35	3
4	28	2.91	37.925	3
3	25	2.85	42.29	3
2	22	2.78	49.108	3
1	19	2.66	54.888	3

where,

MU – Monetary Unit;

PSI – Present Serviability Index.

The range of the analysis intervals (*k*) is a choice made by the manager, since these intervals limit the cost analysis and /or the return of the capital invested in pavements. It means that if there is any interest to know the value of the return of all the investment budgeted for pavements in 2005, it will be necessary to include additional scenarios in such a way that  $I_1=0$ . Only in this way the consecutive deficits of such restrictions can be obtained.

The analysis period can also be defined by the manager. In this work, a two year period has been adopted (2005/2006), but the procedure may be consecutively applied alongside longer period.

All the simulations on the PMS were generated in a macro economical scenario of zero inflation to capture only the effects of the degradation of pavements.

**The Unit Nominal Rates  $r_j$  and the Accumulated Unit Nominal Rate  $i_j$  of the return of the capital invested in pavements**

It is possible to obtain a regression equation type  $I_k = AL_k^n + B$  from the graphic generated by the investment data in table 1. Deriving this equation in relation to  $L_k$  a punctual rate, expressing the proof  $I_k/L_k$ , is obtained. This rate is the degrading rate of the pavements financially shown, according to equation 1. It is important to highlight the fact of adopting a regression equation to represent the relation  $I_k \times L_k$ , the data which are being handled are not the real ones anymore, it means, not the data which originated that equation (table 1) but the ones forecasted by it. A security interval can be defined for these values according to the reliability target.

$$\frac{I_k}{L_k} = \left| \frac{df(I_k)}{dL_k} \right|, \quad 0 \leq k \leq n \tag{1}$$

The right side of equation 1 is the function that represents all the punctual rates  $I_k/L_k$ . In this way, when integrating this function within any interval ( $I_k, I_{k-1}$ ), it is possible to obtain the unit rate which expresses the effect, in  $L_k$ , of the removal/increase of a capital unit  $I_k$ , as shown by equation 2. This rate is named as Unit Nominal Rate  $r_j$ .

$$r_j = \left| \int_{I_{k-1}}^{I_k} \frac{df(I_k)}{dL_k} dI_k \right| = \left. \frac{f(I_k)}{I_k} \right|_{I_{k-1}}^{I_k}, \quad 0 \leq j \leq k-1 \quad (2)$$

The *Accumulated Unit Nominal Rate*  $i_j$  can be obtained if the succeeding  $r_j$  are accumulated as shown by equation 3.

$$i_j = r_j + i_{j+1} \quad (3)$$

Picture 1 shows the graphic  $I_k \times L_k$  for the case being studied (table 1). On table 2 all the investments  $I_k$  made in the case and its respective rates  $r_j$  e  $i_j$  can be observed.

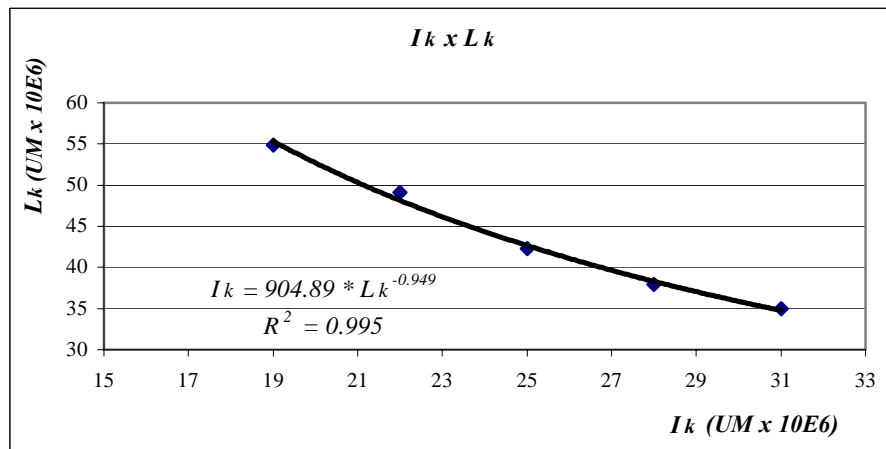


Figure 1 - Curve  $I_k \times L_k$  (Investment in 2006)

<b>k</b>	$I_k$ (MU x 10E6)	<b>A</b>	<b>B</b>
		$r_j = \left  \int_{I_{k-1}}^{I_k} \frac{df(I_k)}{dL_k} dI_k \right $	$i_j = r_j + i_{j+1}$
13	<b>31</b>		
12	30	1.099	1.099
11	29	1.173	2.272
10	<b>28</b>	1.255	3.527
9	27	1.345	4.872
8	26	1.446	6.318
7	<b>25</b>	1.558	7.876
6	24	1.685	9.561
5	23	1.827	11.388
4	<b>22</b>	1.989	13.377
3	21	2.174	15.551
2	20	2.385	17.936
1	<b>19</b>	2.629	20.565

Table 2 - Unit and Accumulated Rates of the Removal Costs of the Capital invested in Pavements in 2005

**The Annual Unit and Average Cost originated by the removal of investments in pavements in 2005**

One of the issues under study is eliciting the annual cost of removal of each capital unit of investments made in pavements in 2005 in order to give basis to the decisions made by the board of directors of company. Column A of table 2 provides such basis, showing that, for the case being studied, the first monetary unit removed in 2005 will lead to a costs of 9.9% per year and the last one to 162.9% per year. Column B shows the actual average annual cost obtained by the removal of the 12 MU, according to equation 4.

$$\bar{i}_{ef} = \frac{20.565}{31-19} = 71,4\% a.a. \quad (4)$$

**The Unit and Average Return Rate of Investments made in Pavements in 2005**

In case the company is in a budget restriction scenario, we can calculate the unit nominal and average return rate of the capital invested in pavements in 2005. This information can support, for example, decisions about the limits for fundraising from shareholders and/or from the financial market to invest in pavements. In order to have a better layout, the data from table 2 were reassembled in table 3.

k	$I_k$ (MU x 10E6)	A	B
		$r_j = \left  \int_{I_{k-1}}^{I_k} \frac{df(I_k)}{dL_k} dI_k \right $	$i_j = r_j + i_{j+1}$
13	<b>19</b>		
12	20	2.629	2.629
11	21	2.385	5.015
10	<b>22</b>	2.174	7.188
9	23	1.989	9.177
8	24	1.827	11.005
7	<b>25</b>	1.685	12.689
6	26	1.558	14.248
5	27	1.446	15.694
4	<b>28</b>	1.345	17.039
3	29	1.255	18.293
2	30	1.173	19.466
1	<b>31</b>	1.099	20.565

Table 3 - Accumulated and Unit Rates of Return of Capital invested in pavements in 2005

It is now possible to elicit, for the case being studied, the annual nominal rate of return for each capital unit apportioned for the investments made in pavements besides the

initial 19MU in 2005. Column A in table 4 shows that the first monetary unit apportioned will have a nominal rate of return of 162.9% per year and the last one will have a rate of 9.9% per year. The shareholder(s) may choose whether to initially apportion capital from the financial market or from his/her own capital on the units of lower rate of return, or vice-versa. Column B, shows the actual annual average of the nominal rate of return of the 12 MU apportioned in this case, as shown by equation 4. On the following items, we are going to propose a conceptualization and quantification of the risks associated with the investments in pavements.

## **OPERATIONAL RISKS ASSOCIATED WITH THE INVESTMENTS MADE ON THE SUB-SYSTEM “PAVEMENTS”**

### **General Issues**

The subject *Operational Risks of the sub-system “Pavements”* can lead to a long discussion in order to provide a minimum scope containing a definition, a classification, an identification, prevention, soothing, control and monitoring. It is not within the goals of this work to discuss explicitly and in detail about all these aspects. The main goal is trying to obtain objective results through some concepts of Operational Risks adapted to the sub-system “pavements”. Thus, it is assumed that the reader is familiar with the concepts used alongside this text and to which too explicit definition is given.

### **Types of Risk**

Operational risks are normally divided in *credit risks, strategic risks, market risks and operational risks* (Marshall, 2002). However, the operational risks are the ones which are focused on this work, due to the fact that they are associated with technological, process, control and human failures. In order to narrow this focus even more, the risk spectrum analyzed herein is particularly linked to the process of supplying and maintaining the road infra-structure of the three concessionaries under the management of Consórcio Univias, which can keep a varied level of correspondence with the risks from other investment agents in pavements.

This project tried to identify the risks related to the critical process of the company, in such a way that mapping and deeply getting to know this process may help while demonstrating the interactions among the various stages, which are daily sources of risks. Besides this, the Pareto Principle was assumed since the very beginning, what means that the majority of the risks arise from a small number of occurrences, since the activities linked to the sub-system “pavements” result from process called *mature*, where the most critical risks may have already been eliminated throughout the time. The probability of occurrences was based on the history of the company, if it exists. This assumption leads to the hypothesis that the future can be predicted once the past is known, what is a feasible assumption taking into account the few drastic changes on the processes associated with the sub-system pavements. If there is the need to forecast less frequent occurrences, other techniques should be used (Marshall, 2002).

The events which cause losses are classified (Marshall, 2002), according to their controllability, into: uncontrollable events and partially controllable events. This classification has not been ignored in this work, but the quantification of risks was

performed, whenever it has been possible, independently from it, through disaggregating the events in order to isolate the controllable steps from the remaining ones. Dominating the biggest group as possible of controllable occurrences/stages may be a differential feature in the risk analysis of the process as a whole, once this class of events is not generally diversifiable, what means that the shareholder should consider it as a non-dissociable part of the process. Procedures for the diversification of losses have been suggested for all the classes of events, whenever possible, generally through the transference to agents more capable of managing them. Table 4 shows the main characteristics of the events analyzed in this work.

<b>Process</b>	<b>Occurrences</b>	<b>Controllability</b>
Restoration with HMA	Master File	Partially Controllable
	Project	Controllable
	Manufacturing Process	Partially Controllable
	Execution	
	Traffic	Uncontrollable
	Weather	Uncontrollable
	Market Variations	Uncontrollable
Surface Treatment	Execution	Partially Controllable

Table 4 - Characteristics of the losses events for two critical processes

## **DISTRIBUTIONS AND FORECAST OF LOSSES – CONTROLLABLE AND PARTIALLY CONTROLLABLE RISKS**

### **History of the Analysis of the Manufacturing Process of HMA**

The partially controllable risks originated by the manufacturing process of Hot Mix Asphalt can be determined by means of the history data of Consórcio Univias. These data refer to the restorations made with HMA in the three toll roads managed by Univias during 2003/2004 and show a consumption of 18,100 tons in 2003 and 38,000 tons in 2004. This material was provided by different suppliers, either Drum Mixer plants or Batch mixing ones.

The history compiled allows managerial statistical analysis under considering different criteria, such as type of producing plants, which toll road, which period, binding rate, granulation measurement, global analysis or the combination of two or more criteria. However, such ramifications are outside the scope of this work, which will consider only the risks related to processing according to the road pole and to the type of producing plants. The probabilities are obtained from the historical relative frequencies, considering the event “asphalt contents outside the working range casualties”.

In Appendix I, there are the frequency distributions of more than 3,100 loads of HMA which are only a reference, once there is the hypothesis that a physical process which has been projected, repeated and controlled should generate results under a normal distribution (Triola, 1999). This hypothesis has been evaluated through the adherence test *Kolmogorov-Smirnov* (Milone, 2004). These tests were held for many theoretical distributions, at a significance rate of 5%, which is an average similar to the content



project of mixtures and the standard deviation is equal to the fourth part of the work range of the mixture project. A significant parcel of the data adjusted to the Normal distribution, but some adjusted better to other theoretical distributions, such as Binomial, Weibull and Poisson. These distributions are based on a consistent subjacent theory, which allows reaching conclusions which are beyond the history data (Marshall, 2002), revealing some important characteristics of the processes evaluated, which is also an issue not abridged by this work.

### **Risks regarding the manufacturing process of HMA in Consórcio Univias**

On table 5, there are the risks/failures of the manufacturing process of HMA when they tried to reach the work ranges of the binding tenor in the mixture projects. The risks were balanced taking into account the amount produced at each period and the probabilities are based on the frequency related to the “hot mix asphalt contents outside the work range” observed in 2003/2004.

Toll	HMA Loads		Failures (unity)		Average Risk (%)
	2003	2004	2003	2004	
Convias	360	478	19	17	4,3
Sulvias	126	1.012	29	219	21,79
Metrovias	520	614	30	50	7,05
Total Risk $\theta_1$					11,7

Table 5 - Risks according to the tolls and global risks originated in the manufacturing process of HMA

Once we get the risk rate originated by the manufacturing process of HMA, there is one question to answer: can this risk be diversified and transferred to the supplier, for example? In a negative case, at least two alternatives can be considered on the company’s budget for that period; 1) there must be a financial accrual for these casualties or 2) the rate R obtained on table 6 is subtracted from the average annual effective rate of recovery of the capital invested in pavements shown by equation 4 (if there is a need) or, in case of reduction of the investments in pavement, the processing risks should be considered as an additional cost.

Being not diversifiable, the controllable and/or partially controllable risks can be subjected to the direct actions from the units in charge of the process. If those units can not avoid them, they could, at least, reduce the sensitivity of the company to them, in such a way that the managerial actions must be far beyond simple considering them on the financial balance sheet of the period.

### **Risks involving master files and structural projects**

The risks associated to the reliability on the master file information (raw materials and the thickness of layers and the construction date of them, control parameters of the actual conditions of the pavements, such as load tests, surface evaluations, etc.) can be considered by the project designer through the definition of the reliability level (AASHTO, 1993) of the project (NC). This measurement of NC will provide, in practice,

the admission of intervals for the failures/risks casualties which may occur alongside the project period (PP) allowed.

The capitalization of such risks can be considered in three alternate ways: 1) At the moment of the initial investment, 2) Linearly distributed alongside the whole PP interventions and 3) distributed alongside the whole PP interventions, but considering the time elapsed between the service execution and risk analysis period. The first alternative allows all the future investment anticipations to recover any project failures to be capitalized at the moment of the initial investment and a discount rate of the future anticipations can be used. The remaining alternatives will have the future investment anticipations capitalized at the moment the casualty occurs, which is when the third alternative seems closer to reality, once the failure casualties in interventions with HMA are not generally immediate. Thus, if the project NC complement is considered as a master file and project risk, the manager will have the power to allocate these costs in the company's financial budget. Equation 5 represents the most general case, it means, the third alternative of investment allocation mentioned before.

$$\theta_2 = \frac{1}{\sum_1^n C_i} \sum_1^n \frac{a_i C_i (1 - NC_i)}{PP_i} \quad (5)$$

where,

$\theta_2$  = Master file and structural project risks;

$a_i$  = Annual Weighting Factor, where  $\sum a_i = 1$ ;

$C_i$  = Implementation Cost of each project;

$PP_i$  = Project Period;

$NC_i$  = Reliability Level of the Projects.

The degree of controllability of the Master File and Structural Project risks can vary according to the company. However, the main focus of the risk management-engineering department must be the perfect knowledge over the internal steps of this process. At Consórcio Univias, where this risk class is totally controllable, the structural project process has been divided into two large groups synchronized by the PMS: 1) Maintenance of pavement history, 2) Annual Monitoring of the functional and structural conditions of the pavements. At the PMS, at a project level, a great deal of attention has been paid to a series of other parameters, but the focus of the managerial actions was kept on the performance of the asphalt mixtures. Such data have been obtained from researches done in Universities or in their own laboratories. It is believed that the greater parcel of aggregated value of the Project NC is concentrated in these three activity groups and as consequence, the minimization of master file and structural project risks.

### **Executive Process Risks**

It is suggested to apply, as a management scope of the risks originated by the building processes, Quality Control (QC) procedures over the paving services to quantify them,

such as the concepts of Pay factor (PF) and the concepts of Technological Control (TC) for their minimization. Considering the case of the road concessionaires, this format can operate at a relatively high level of success, since the companies can act in two complementary ways, using their own resources to minimize the building risks using TC procedures and adopting ways to diversify this type of risk, transferring it to the contractor, for example, who should be an agent capable of managing it. In this context, all the concepts expressed in the item 4.2 about the capitalization of master file and project risks can also be adapted to the executive process risks. These risks would then be classified as diversifiable and partially controllable risks, quantitatively expressed by the PF as shown by equation 6.

$$\theta_3 = \frac{1}{\sum_1^n C_i} \sum_1^n \frac{a_i C_i (1 - FP_i)}{PP_i} \quad (6)$$

where,

$\theta_3$  = Executive process risks;

$a_i$  = Annual Weighting Factor, where  $\sum a_i = 1$ ;

$C_i$  = Implementation Cost of each project;

$FP_i$  = Pay factor;

$PP_i$  = Project Period.

## LOSS ESTIMATION OF UNCONTROLLABLE RISKS

These risks, by definition, cannot be controlled by any unit of the company (Marshall), because they are external contingencies of the processes of the sub-system Pavements. An exception to this class, which was also classified herein because of the incipient existent control stage, was the risk originated by the traffic, more precisely, the load excess on the commercial fleet circulating on the Brazilian Roads.

Consórcio Univias has many history data of the weighing procedures on the roads managed by it, obtaining its own Vehicle Factors through the PMS, in such a way that the financial impact of this risk is already explicitly considered on the values shown on table 1. Because of this, its financial impact is already subtracted from the rate shown by equation 4. Similarly, the risks originated by the weather are also considered in that table, it means, the PMS explicitly considers the temperature variations and the rainfall during the year.

Regarding the market oscillations, their forecast remains as an unknown value, because the calculation of its impact will be straightforward, but the annual inflation appears as a natural candidate to add to this factor, even though there is a historical detachment of this indicator and the variation of the asphalt raw materials. Thus, in the case of Consórcio Univias the variation of costs for the raw materials alongside the year is limited to the risks which are totally uncontrollable and as first approximation, it is suggested the adoption of the annual inflation to quantify this effect, as shown by equation 7.

$$\theta_4 = i_{ano} \quad (7)$$

where,

$\theta_4$  = Cost risks;

$i_{ano}$  = Annual inflation.

In the situation which the traffic and weather data cannot be directly and explicitly considered, it is suggested to apply scenario simulation methods, such as the *Monte Carlo* method (FHWA, 1998).

## CONCLUSIONS

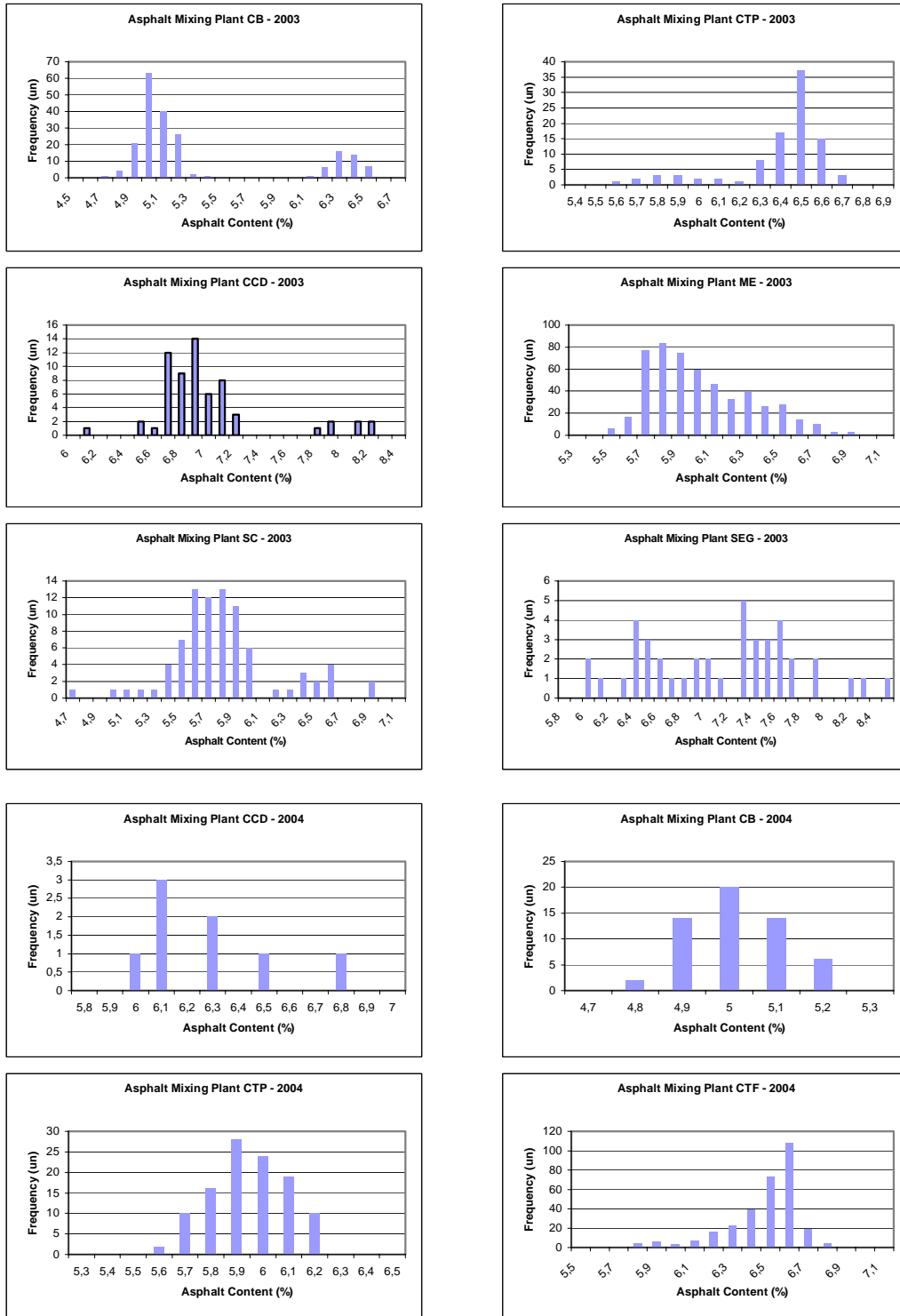
The imposing factor over the recover and/or capital cost invested in pavements is, for sure, the PMS available for the analysis, which must be able to deal with all the aspects acting over the complex issue of managing road networks, such as master file information, the methodology adopted for monitoring the pavements and the performance forecast methods used at the project and at the network level, among others. When these issues are satisfactorily referred, the procedure herein presented will be able to generate reliable information to demonstrate the financial impact generated by the technical decisions made by the company's board of directors.

When considering all the risks indicated in this work and maybe other risks, such as the one related to managerial issues, or financial, institutional and /or regional risks (which have been neglected in this work), it is possible to widely bypass the impact of the failures related to the sub-system pavements. The initial task of the risk management team from the pavement engineering is identifying the main processes of this sub-system and know them in detail, because the diagnosis will be based on it, as well as the prevention and mitigation of related risks.

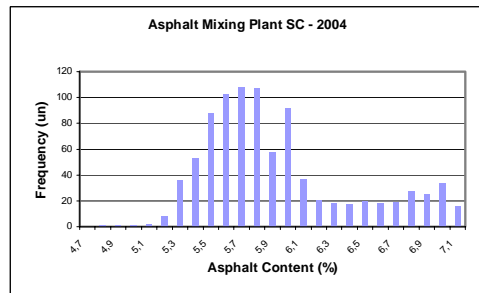
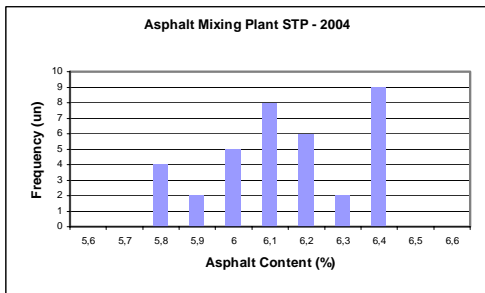
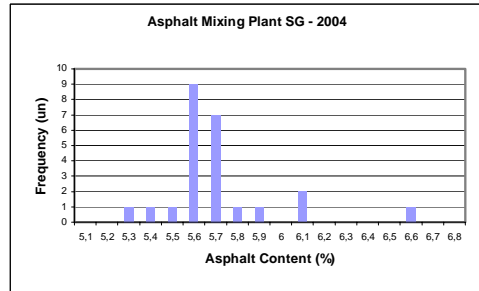
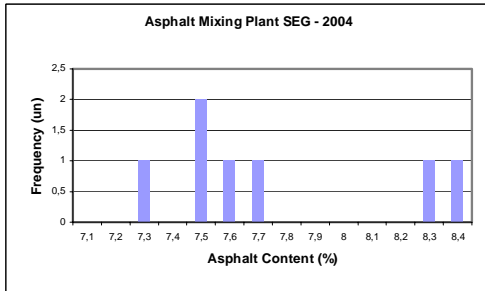
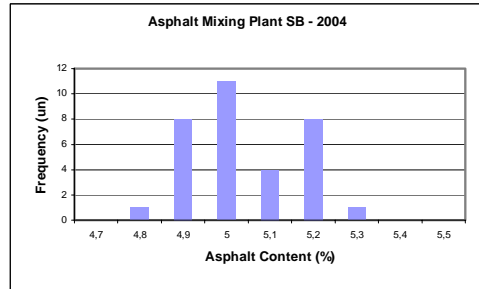
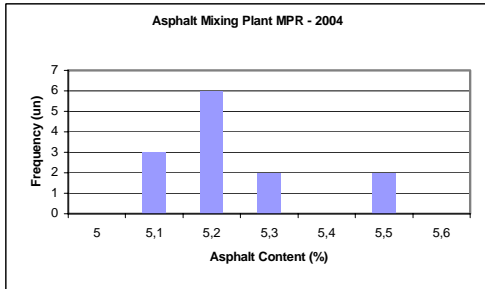
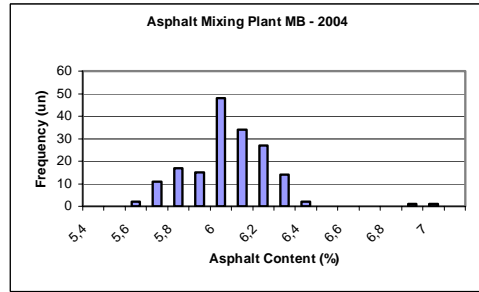
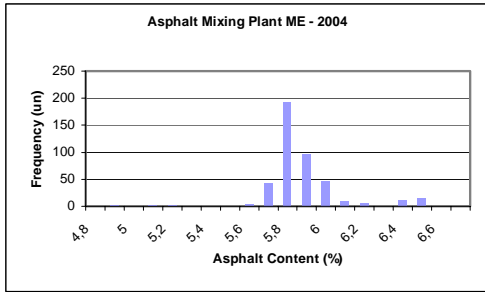
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## Appendix I – Distribution of the asphalt content in HMA



Distribution of asphalt contents frequency in the three Toll Road Concessionaires (2003/2004) – Collection I



Distribution of asphalt contents frequency in the three Toll Road Concessionaires (2003/2004) – Collection II