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Asset Valuation Model for Highway Rigid Pavements Applicable in Public–Private Partnerships Projects †

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Abstract: Recently, in Chile, infrastructure asset value has been incorporated into highway concession contracts. However, the current valuation model used for rigid pavements is not adapted to the standards and conditions of such projects. This study develops a valuation model for rigid pavements of interurban highway concessions and evaluates it in a case study. The proposed model captures the loss in asset value associated with the performance degradation over time, considering a typical Jointed Plain Concrete Pavement (JCPC) configuration. The value is calculated using performance indicators that represent the structural capacity and level of service provided to road users. The model represents a significant improvement compared to current asset valuation models used in highway concessions. It enables the public agency to objectively evaluate the preservation of asset value carried out by the private partner during the concession. Additionally, it could also be used as a tool to establish payments between infrastructure stakeholders. Some of the concepts applied could also be relevant for other highway assets existing in Public–Private Partnership (PPP) projects.

Keywords: highway asset management; highway asset valuation; infrastructure asset; rigid pavement; pavement performance; public–private partnership

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1. Introduction

Asset valuation has been defined as the process of estimating the value of a physical asset on a specific date [1,2]. It plays a crucial role in highway asset management by helping justify infrastructure financing needs, ensuring proper use of taxpayer funds and evaluating investments in monetary terms, among other aspects [1–3]. However, it has been noted that infrastructure asset valuation can be ambiguous and may carry different meanings across various disciplines [2]. In fact, there is no universally accepted valuation method [1] and the selection of the most suitable method depends on the objectives of the infrastructure stakeholders [4]. Also, the selection of the valuation method depends on the characteristics of each highway asset, such as pavements, bridges, culverts or signals [5].

Valuation methods for highway assets can be based on their costs, benefits or market value. Cost-based valuation methods consider the costs incurred in asset construction or replacement [3,6,7]. Benefit-based valuation methods consider the benefits that the assets provide to society, such as savings in travel time, vehicle operating costs and other economic factors [8,9]. Also, benefit-based methods may consider the income generated by the road administrator or owner, as is the case with toll roads [4,10]. Market-based valuation methods consider the price that a buyer is willing to pay for the assets, based on recent sales of similar assets in the market [1,4].

Cost-based valuation methods are considered most appropriate for highway assets since they are not typically designed to generate income [6]. Within these methods, costs can be adjusted using either the "Depreciation" or "Modified" approach [3,11,12]. The former adjusts the cost according to a linear or curvilinear function predefined for the asset's service life, while the latter adjusts it based on the asset's current condition. These methods are widely utilized by transportation agencies at the local and state levels worldwide to fulfill management and financial requirements [1,2]. The "Modified" approach is particularly advantageous for management purposes as it considers the asset's condition during valuation [3,11,12]. Examples of specific methods within this approach are the Net Salvage Value (NSV), Written-Down Replacement Cost (WDRC) and Adjusted Value with Respect to Condition Threshold (AVRCT) [11].

Public–Private Partnerships (PPPs) are mechanisms that allows private participation in the development and management of public infrastructure projects [10,13]. The use of this mechanism has increased recently, with the public sector expressing significant concerns about the private operator's ability to preserve the value of the infrastructure over time [6]. In Chile, the infrastructure asset value has been recently incorporated into highway concession contracts, to establish a final payment from the state to the concessionaire upon contract completion [14,15]. The payment depends on the final value of the infrastructure returned to the public agency by the private partner. For pavements, which can account for over 50% of the total value of a highway concession [16,17], the NSV method is employed. The asset value is calculated by subtracting the cost of operations required to restore the asset to its "as-new" state from the construction cost [3,18]. However, the NSV method is not adapted to standards for pavements of highway concessions [17]. Originally developed for evaluating the country's public road network value for financial purposes [18], the method fails to consider crucial aspects in valuing highway concession assets. Examples of this aspects are managing contract risks [13], incorporating only factors under the private operator's control [6] and being compatible with the level of service to users [19].

A valuation model for asphalt pavements of interurban highway concessions was developed by Marzal et al. in 2021 [20]. This model incorporates technical indicators and rehabilitation activities that are specifically adapted to the standards and objectives of such projects. However, in the case of Portland Cement Concrete (PCC) pavements, also known as rigid pavements, a model with such characteristics has not yet been developed. In fact, most of the studies found in the available literature include valuation models for pavements at the network level, without differentiating between rigid and flexible pavements [1,3,11,21–23]. On the other hand, rigid pavements can comprise up to 25% of the lane length in interurban highway concessions in Chile [16,17]. Therefore, the development of a valuation model specifically designed for rigid pavements applicable in this type of projects becomes necessary.

This study aims to develop and evaluate a valuation model for rigid pavements of highway concessions that incorporates their structural and functional capacity [24,25]. The proposed model considers a typical Jointed Plain Concrete Pavement (JCPC) configuration and is applied in a case study to assess the captured asset value loss over time. The results obtained from the case study demonstrate the potential implementation of the proposed model for evaluating the concessionaire's preservation management. This would provide the state with a more effective tool to achieve that objective, as the proposed model exhibits higher precision and accuracy levels compared to the current valuation model. The higher precision is attributed to the use of clearer calculation procedures and the inclusion of factors that are contractually dependent on the concessionaire. The higher accuracy is achieved by considering standards that effectively align with interurban highway concessions in the operation phase.

This paper is divided into five sections. Section 1 provides the introduction. Section 2 presents the development of the valuation model for rigid pavements, including all the equations and data necessary for the calculation of asset value. Section 3 focuses on the application of the proposed model in a case study, outlining the data processing procedures and presenting the obtained results. Section 4 entails the discussion of the results, along with recommendations and limitations of the study. Lastly, Section 5 concludes the study and highlights potential opportunities for future research.

2. Development of the Valuation Model for Rigid Pavements

The valuation model is based on the Net Salvage Value (NSV) method. Consequently, the pavement value is determined by the difference between the construction cost and the cost of rehabilitating it to its "as-new" condition. Both costs must be based on the unitary costs defined in the PPP contract at the bidding moment. It is essential that the unitary costs used in the model remain consistent across different evaluation years. This approach is employed to mitigate the risks of the concession contract, by not incorporating aspects beyond the control of the concessionaire, such as changes in construction technologies, inflation or other economic factors.

2.1. Technical Indicators of the Proposed Model

The valuation model incorporates performance indicators that represent the functional and structural condition of the pavement, which are presented in Table 1.

Table 1. Rigid pavements characteristics and technical indicators.

Characteristic	Technical Indicator	Unit
Roughness	Mean Roughness Index (MRI)	m/km
Friction	Sideway Force Coefficient (SFC)	-
Rolling noise	Overall A-weighted Sound Intensity Level (OASI)	dBA
Load transfer	Load transfer efficiency percentage (LT)	%
Cracking	Percentage of cracked slabs (CRK)	%
Potholes	Percentage of potholes (PP)	%

The first three indicators of Table 1 (MRI, SFC and OASI) have been incorporated into a model for evaluating the level of service provided to the highway users. That model was developed in the research project FONDEF IT16I10008 and is currently being implemented in contracts of Chilean interurban highway concessions [19].

In the aforementioned project, it was established that indicators LT, CRK and PP are not directly linked to the level of service for users but rather to the asset value for the infrastructure owner. For example, cracking is not directly relevant to users as its impact on their comfort is captured through the MRI indicator. However, the presence of cracking is relevant for the State as it reflects the structural deterioration of the pavement and indicates the need for rehabilitation. Therefore, the proposed model also incorporates these last three indicators, for which the measurement methodology was developed in the research project FONDEF ID20I10072 [26]. Indeed, this project resulted in a valuation model for assets of highway concessions, including rigid pavements through the model proposed in this study.

The indicators MRI, SFC, CRK and PP should be evaluated and reported for 50 m sections. The OASI indicator should be evaluated and reported in 200 m sections. As for the LT indicator, it should be reported for 250 m sections, with at least 15% of the slabs in these sections being evaluated. It is desirable that the slabs evaluated for obtaining LT values are consecutive and do not exhibit cracking. Then, the LT value for the 250 m section corresponds to the average of the LT values obtained for the evaluated transverse joints. LT values that exceed the average by more than two standard deviations are not considered. A summary of the measurement methodology for technical indicators considered in the proposed model is presented in Table 2.

Table 2. Summary of measurement methodology for technical indicators of rigid pavements.

Technical Indicator	Frequency of Testing	Measurement Equipment	Normative(s) to Follow
MRI	Annual	Inertial profilometer (class 1)	ASTM E950
SFC	Annual	SCRIM, grip tester or runway friction tester	MC 8.502.17 [27]; MC 8.502.18 [27]; ASTM E2340M
OASI	Annual	OBSI measurement system	AASHTO T360
LT	Once every 3 years	Falling weight deflectometer (FWD)	MC 8.502.5 [27]
CRK	Annual	Crack measurement equipment C2221	AASHTO PP 68
PP	Annual	T1111 profilometer + Visual inspection	ASTM E-1656 MC 8 Appendix [27]

2.2. Equations and Required Data to Apply the Proposed Model

For the valuation, the highway is divided into sections of 50 m in length for each lane. The value of each rigid pavement section is determined using the following equation:

$$V_t = \begin{cases} CC - RC_t & ;if\ RC_t \le CC \\ 0 & ;if\ RC_t \ge CC \end{cases} \tag{1}$$

where CC represents the construction cost of the section and RC_t corresponds to the rehabilitation cost of the section at time "t". The equations necessary to calculate the rigid construction and rehabilitation costs of the pavement section are provided in Table 3. These equations were developed by Arce in 2023 [28], as part of the research project FONDEF ID20I10072 titled "Highway Valuation Methodology Compatible with the Level of Service to the Users" [26]. The subscript "t" in Table 3 indicates that the parameter or variable is calculated at time t. All the cost and geometric parameters in the table can be expressed in United States Dollars (USD) and meters, respectively.

Table 3. Equations to calculate rigid pavement section construction and rehabilitation costs.

Equation (Number)	Description of Variables and Parameters
$CC = B \cdot L \cdot (UC_{SG} + \sum_{i=1}^{N} UC_i \cdot H_i)$ (2)	B; L: Lane width and section length, respectively. UC_{SG}: Subgrade preparation unitary cost. N: Number of pavement layers in the section (subbase and/or base, and concrete slabs). UC_i; H_i: Layer "i" unitary cost and thickness, respectively.
$RC_t = m\acute{a}x\{RC_{PPt},\ RC_{PIt}\}$ (3)	RC_{PPt}; RC_{PIt}: Rehabilitation cost associated with potholes and performance indicators, respectively.
$RC_{PPt} = \begin{cases} B \cdot L \cdot UC_{Rec} & ;if\ PP_t > 0\% \\ 0 & ;if\ PP_t = 0\% \end{cases}$ (4)	UC_{Rec}: Reconstruction unitary cost (existing pavement removal or recycling cost, plus the construction cost).
$RC_{PIt} = RC_{CRKt} + RC_{LTt} + m\acute{a}x\{RC_{MRIt}, RC_{SFCt}, RC_{OASIt}\}$ (5)	RC_{CRKt}; RC_{LTt}; RC_{MRIt}; RC_{SFCt}; RC_{OASIt}: Rehabilitation cost associated with cracking, load transfer, roughness, friction and rolling noise, respectively.
$RC_{CRKt} = B \cdot L \cdot UC_{SR} \cdot CRK_t$ (6)	UC_{SR}: Concrete slab replacement unitary cost. CRK_t: Percentage of cracked slabs.
$RC_{LTt} = (S_t - S_{CRKt}) \cdot 6 \cdot UC_{DBR} \cdot P_{LTt}$ (7)	S_t; S_{CRKt}: Number of slabs and cracked slabs, respectively. UC_{DBR}: Dowel bar retrofit unitary cost (it is multiplied by 6 since 3 bars are installed per wheel path at each joint). P_{LTt}: Loss percentage associated with load transfer.
$RC_{MRIt} = B \cdot L \cdot UC_{DG} \cdot P_{MRI_t}$ (8)	UC_{DG}: Diamond grinding unitary cost. P_{MRI_t}: Loss percentage associated with roughness.
$RC_{SFCt} = B \cdot L \cdot UC_{DG} \cdot P_{SFC_t}$ (9)	P_{SFC_t}: Loss percentage associated with friction.
$RC_{OASIt} = B \cdot L \cdot UC_{DG} \cdot P_{OASI_t}$ (10)	P_{OASI}: Loss percentage associated with rolling noise.

The loss percentages associated with the indicators have values of 0%, 25%, 50%, 100% and 200% if their performance levels are Very Good, Good, Fair, Poor and Very Poor, respectively. The determination of the performance level depends on predefined thresholds set for each technical indicator, as presented in Table 4. These thresholds were defined in accordance with international norms and regulations for high-standard highways [19]. It is important to highlight that MRI has different thresholds for 50 m and 1 km sections. Also, it should be noted that the thresholds for CRK are presented in Table 4 but are not utilized in the proposed model. Indeed, the model directly considers the cost of replacing the slabs that exhibit cracks of any type and severity.

Table 4. Performance-level thresholds for each technical indicator.

Performance Level	MRI [m/km] (50 m)	(1 km)	SFC [-]	OASI [dBA]	CRK [%]	LT [%]
Very Good	[0.0, 1.5)	[0.0, 1)	(0.65, 1.00]	≤100.0	[0, 5)	≥70
Good	[1.5, 2.5)	[1.0, 2.0)	(0.55, 0.65]	(100, 102]	[5, 10)	[60, 70)
Fair	[2.5, 3.5)	[2.0, 3.0)	(0.40, 0.55]	(102, 104]	[10, 15)	[50, 60)
Poor	[3.5, 5.0)	[3.0, 4.5)	(0.20, 0.40]	(104, 106]	[15, 20)	[40, 50)
Very Poor	≥5.0	≥4.5	[0, 0.20]	>106	≥20	<40

In addition to the previously presented tables, Figure 1 displays a data flow chart illustrating the process for calculating the value of a rigid pavement section.

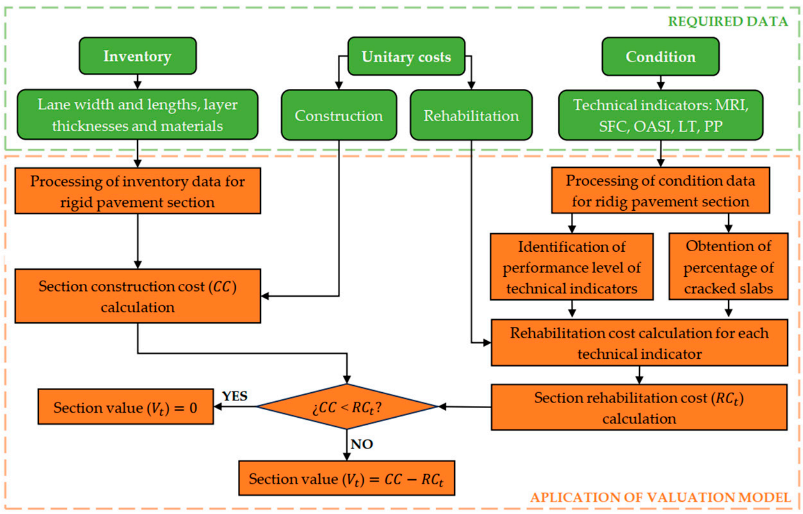

Figure 1. Data flow chart with the process of value calculation for a rigid pavement section.

Finally, the total value of the rigid pavement on the highway is calculated by summing the value of all 50 m sections. This same approach is also applied to calculate the total construction and rehabilitation costs.

2.3. Additional Comments about the Proposed Model

The rehabilitation cost of the chosen rehabilitation activities presented in Table 3 enables the determination of the value loss associated with each performance level. It should be noted that the selected rehabilitation activities are just one possible set of activities among many that could be employed. Therefore, they may not necessarily represent the actual preservation strategy to be implemented by the concessionaire.

It is important to acknowledge that the equations presented in Table 3 are specifically applicable to Jointed Plain Concrete Pavements (JPCP). In fact, this is the typical configuration of rigid pavements commonly found on interurban roads in Chile. The equations are suitable for calculating the construction and rehabilitation costs of rigid pavements, if the necessary inventory, condition and cost data are available. The construction cost takes into account the expenses incurred in constructing all the layers present in each pavement section. The rehabilitation cost considers the costs associated with restoring the performance level of each technical indicator in each pavement section. In the case of Chilean interurban highway concessions, the required data regarding pavement layers and indicators are accessible, enabling the application of the proposed model.

The equations provided in Table 3 are designed to ensure that the loss of value corresponds to the cost of restoring the asset to its "as-new" condition. In Equation (3), it is assumed that the slab replacement activity includes dowel bars in transverse joints, so the costs associated with CRK and LT are combined. As indicated in the same equation, the maximum cost between the MRI, SFC and OASI indicators is also considered. This is because it is assumed that the diamond grinding activity is necessary to achieve a "Very Good" performance, even if slab replacement is conducted.

The choice of using 50 m sections is driven by the capabilities of current technology, which allows for the evaluation and reporting of four out of the six indicators (MRI, SFC, CRK and PP) within that section length. The OASI and LT indicators are reported for 200 m and 250 m sections, respectively. However, it can be assumed that the measurement of these indicators is representative for the 50 m sections. Depending on the availability of data, calculations can also be performed for sections of 100 or 200 m, or even 1 km. In Chile, measurements have been conducted with a sampling level lower than that indicated in Table 2, due to contractual requirements. Therefore, if the intention is to apply the proposed model from the previous case, the use of sections longer than 50 m would be more appropriate.

3. Case Study

3.1. Route Description, Available Data and Data Processing

A case study was carried out in an interurban highway concession, located in the central zone of Chile. The highway consists of both flexible and rigid pavements and is divided into four lanes. The total length of the highway is 442 lane-km. Specifically, the rigid pavement of the roadway, for which sufficient data was available to apply the proposed model, has a total length of 102 lane-km. A map of the highway is presented in Figure 2 (see next page).

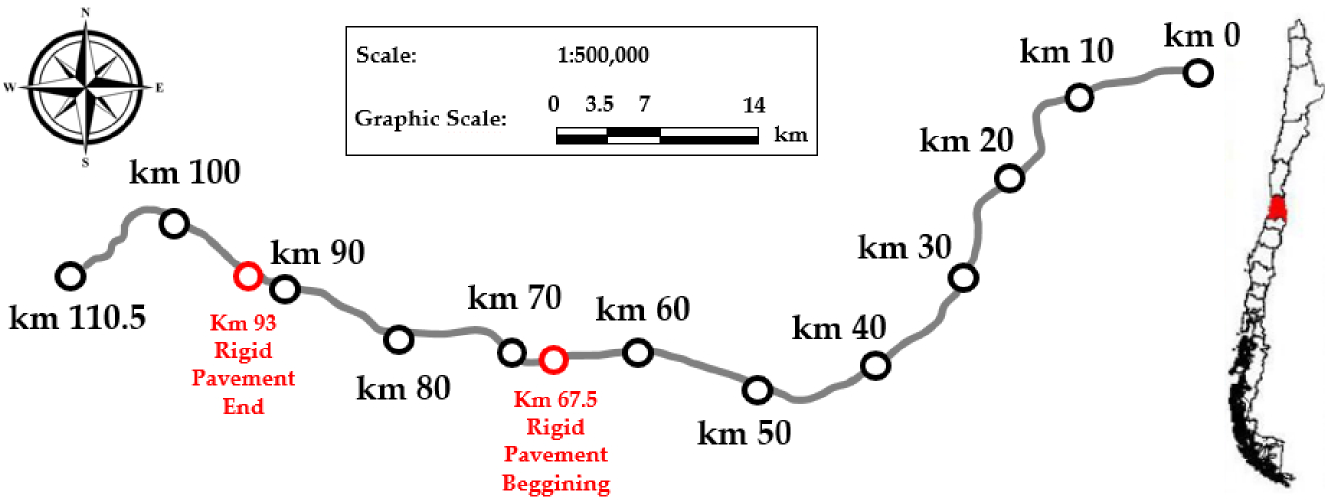

Figure 2. Map of the interurban concession highway of the case study (adapted from the Ministry of Public Works of Chile [17]).

The available inventory data for the rigid pavement includes layer thicknesses. The pavement structure consists of a 15 cm granular subbase (present only in 61.4 km-lane), a

15 cm crushed granular base and concrete slabs with thicknesses of 26 cm for lanes 2 and 4, and 23 cm for lanes 1 and 3. The pavement was constructed in the year 1999.

The available cost data includes the construction and rehabilitation unitary costs, which were obtained from the valuation report specifically developed for this highway [10]. These costs were utilized due to the absence of a defined unitary cost for the dowel bar retrofit activity in the concession contract.

The available condition data was obtained from the functional and structural evaluations conducted in 2007 and 2020. These evaluations include the measurement of the indicators presented in Table 1, except OASI, which has not yet been evaluated in Chilean highways. The MRI, SFC and LT values are reported for each 200 m section of the pavement. However, MRI is not reported in sections with singularities as bridges or toll zones. Also, LT data of 2007 is only available for lanes 3 and 4, which are the slow lanes with heavy traffic. The cracking data came from visual inspection of 40 slabs per kilometer, indicating whether the slabs were cracked or not. Thus, CRK was not reported directly and had to be calculated, assuming it was representative for each kilometer. There was no reported presence of potholes on the pavement.

The percentages of sections distributed by performance level for each technical indicator and year are depicted in Figure 3. These percentages were obtained considering only lanes 3 and 4, using 1 km sections and fixed average values of SFC, MRI and LT for each kilometer. The use of 1 km sections is because the data for the CRK and LT indicators were collected at a lower sampling level than that required by the proposed model.

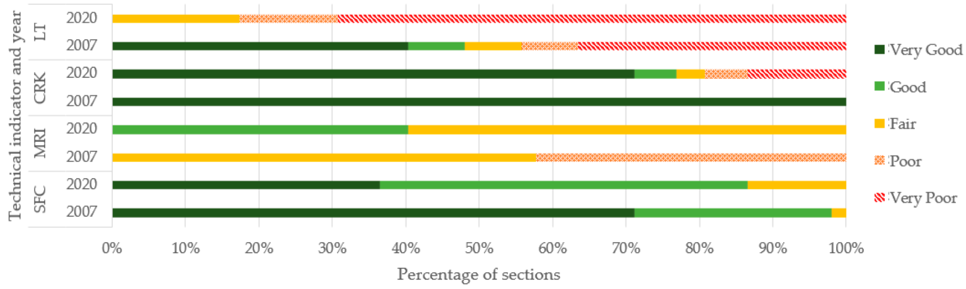

Figure 3. Percentage of sections distributed by performance level in 2007 and 2020.

It could be noted that the performance level of the indicators decreased in 13 years, except for MRI. This can be attributed to the fact that rehabilitation activity, specifically diamond grinding, was carried out in lanes 3 and 4 between 2013 and 2015.

3.2. Results Obtained in 2007 and 2020 for Lanes 3 and 4 Using the Proposed Model

The construction cost of the rigid pavement is USD 9260 thousand, obtained by summing the construction costs for each pavement section calculated by Equation (2). The rehabilitation costs associated with each technical indicator are presented in Figure 4. These costs correspond to the sum of the costs associated with indicators CRK, LT, MRI and SFC for each pavement section, calculated using Equations (6)–(9), respectively. The percentages displayed in the bars represent the values with respect the construction cost.

The total rehabilitation cost and value are depicted in Figure 5. The percentages shown in the bars also represent the values with respect the construction cost. Note that, in Figure 5, the sum of the rehabilitation cost and the asset value does not correspond to 100% of the construction cost. This is because the asset value is calculated for each 1 km pavement section and not for the entire highway, as indicated in Equation (1) and Figure 1. Therefore, the total value does not include the total rehabilitation cost, as the sections with higher rehabilitation than construction costs have a value of zero.

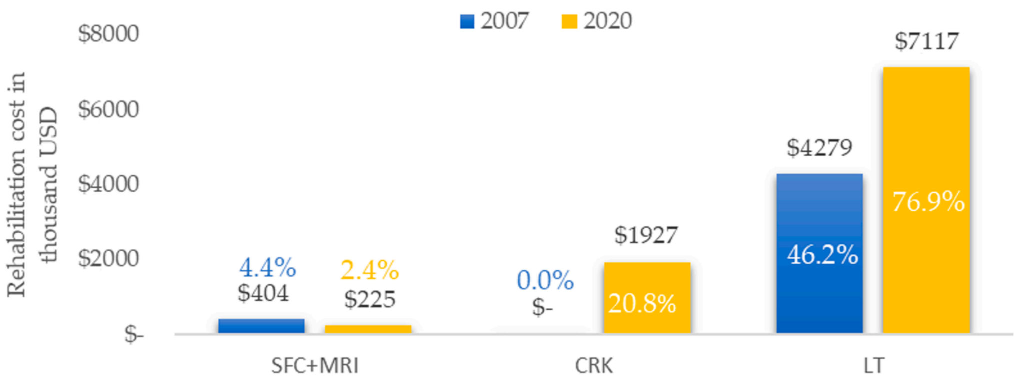

Figure 4. Rigid pavement rehabilitation cost for each technical indicator in 2007 and 2020.

Figure 5. Rigid pavement total rehabilitation cost and value in 2007 and 2020.

The rigid pavement value experienced a significant decrease over the course of 13 years, declining from 50.1% to 12.4% of its construction cost. This decline is primarily attributed to the loss of performance levels in the structural indicators (CRK and LT). On the other hand, the value loss associated with the functional indicators (SFC and MRI) is considerably lower compared to the structural indicators. This is attributed to the lower cost of rehabilitation activities related to functional indicators in comparison to structural indicators. Additionally, the behavior of the concessionaire in fulfilling the requirements of the concession contract plays a role in the observed trends. In fact, the contract's requirements align closely with the thresholds of the proposed model for functional indicators. However, for structural indicators, the contract's requirements are significantly lower [29].

4. Discussion

A fair comparison of the results obtained from the proposed model can only be made with the current model used in Chile for valuing rigid pavements. This is because no evidence was found in the international literature regarding the existence of a model specifically designed for valuing this asset. Most of the studies found in the literature focus on valuing pavements at the network level, without differentiating between rigid and flexible pavements. Examples of such studies include those conducted by Falls et al. in 2004 and 2005 [5,22], Dojutrek et al. in 2012 and 2014 [3,12], Acharya in 2014 [21], Alyami and Tighe in 2016 [1], and Lim et al. in 2019 [23]. These studies employed or compared methods such as Net Salvage Value (NSV), Written-Down Replacement Cost (WDRC), Straight-line Depreciation (SLD), and Elemental Decomposition and Multicriteria (EDMC), among others. However, the methods were analyzed or applied with different databases and valuation objectives from those of the present study.

The current model for Chilean rigid pavements was used in the valuation report of the case study highway using data from 2020 [17]. According to that report, the asset value obtained for the rigid pavement in lanes 3 and 4 was USD 7699 thousand, representing 78.4% of the construction cost. This value is considerably higher than the result obtained in

2020 using the proposed model in this study. The difference can be explained by the specific characteristics and objectives of each model. The proposed model is designed to evaluate the pavement preservation management of concession highways carried out by the private manager at the project level. In contrast, the current model was originally developed to evaluate the overall value of the country's public road network for financial purposes [18].

It can be stated that the proposed model exhibits higher levels of accuracy compared to the current model. The current model assumes uniform pavement thicknesses for all sections based on geographic location and project background [17,18]. However, along the highway, the pavement may have different thicknesses in different sections, which the proposed model acknowledges in Equation (2). Specifically for the case study, this implies a higher construction cost obtained with the current model compared to the proposed model. Furthermore, the current model incorporates condition thresholds that are not aligned to the standards of highway concessions [17,18]. This issue is rectified in the proposed model, which considers the performance levels of technical indicators through appropriate thresholds. Additionally, in the proposed model, rehabilitation costs are determined based on the performance levels of technical indicators, rather than fixed intervention percentages as in the current model [17,18]. As a result, in the case study, the latter characteristics lead to a lower rehabilitation cost obtained with the current model compared to the proposed model.

Additionally, it is important to note that the proposed model demonstrates higher levels of precision compared to the current model, as its calculation procedures are clearer and well-defined. This enables better management of concession contract risks through a precise and objective valuation. In contrast, the current model is part of a valuation methodology for Chilean roads that can yield different results depending on its interpretation [26]. Additionally, the proposed model incorporates fixed unitary costs over time, which are defined in the concession contract at the bidding stage. This, combined with the clarity of procedures, allows for the establishment of conditions prior to highway operation and consideration of aspects that are solely within the control of the concessionaire as stipulated in the contract. On the other hand, the current model considers prices that can be updated annually. Consequently, the valuation provided over time by the current model is subject to external factors beyond the management of the private operator, such as inflation and other economic factors.

Based on the above, the proposed model is suitable for implementation as a management tool in interurban highway concessions. It has the potential to enable the State to evaluate the performance of private operators in maintaining the infrastructure asset value. The implementation can be carried out by the Concessions Directory of Chile by incorporating the model into the bidding terms of future highway concession contracts. To ensure effectiveness, it is important to ensure that the inventory and pavement condition information is collected as required by the model. The model is designed to leverage existing information to minimize data collection costs.

It is crucial to emphasize that the objective of the model is to enable the infrastructure owner to evaluate the performance of private operators. The model is not intended to exert direct control over the management processes, such as determining the timing and specific activities for pavement rehabilitation. These decisions are left to the discretion of the concessionaire, who can utilize their own management systems and strategies. However, the outcomes and results of the concessionaire's actions can be assessed by the State using the proposed model as an evaluation tool. Based on the asset value retained during the operation phase of the highway, the State may establish incentives or penalties for the concessionaire. These incentives or penalties can be expressed through various means, such as financial payments between both parties, or adjustments to the concession terms and fees charged to users.

On the other hand, the proper implementation of the model can bring various benefits to the different stakeholders involved in highway concessions. By calculating the value of the infrastructure continuously and incorporating incentives and penalties for the private operator, it promotes a more efficient management of highway assets. This, in turn, can lead to a better level of service for users and ensure that the public budget achieves greater value for money. In addition, assets that maintain their value over time will deliver the required service for a longer time, increasing the social benefit of investments.

Despite the advantages, potential applications and benefits of the proposed model, it is important to acknowledge its limitations. As mentioned earlier, the model is specifically designed for project-level applications. Using it for network-level management purposes is unrealistic due to the extensive level of detail required for its calculations. In the case of Chile's public road network, most of the condition data are not collected in the manner specified by the proposed model. Therefore, implementing the model in that context could be costly for the State.

In addition, the results obtained in the case study may not accurately represent the actual rehabilitation cost and value of the rigid pavement. An important source of uncertainty is the lack of load transfer data. In fact, this indicator was evaluated in a single joint every 200–500 m and using fixed averages for each kilometer may not faithfully represent its performance level. Moreover, it was assessed at different times of the day for the various pavement sections, which may require correction factors to account for variations in temperature and joint expansion [28]. In consequence, the proposed model may overestimate the rehabilitation cost associated with this indicator and underestimate the value of rigid pavement in the case study.

5. Conclusions

This study aimed to develop a valuation model for rigid pavement assets that incorporates their structural and functional capacity, which are relevant for highways managers and users, respectively. The application of the proposed model in the case study reveals that the asset value diminished after 13 years, mainly due to the loss of structural capacity. On the other hand, the results obtained in 2020 with the proposed model are significantly different from the results reported with the current model. The proposed model has a different objective, which is to evaluate the preservation management of the concessionaire, rather than justifying funding needs. Additionally, it is designed for high-standard highways and provides a higher level of detail in its calculations (project-level instead of network-level). This study is the first that propose an asset valuation model for rigid pavements with such characteristics.

By considering the standards and objectives of highway concessions, the proposed model has the potential to be implemented by the Concessions Directory of the Ministry of Public Works of Chile. It can be utilized as a tool for evaluating the management performance of the concessionaire at the project level. However, the effective implementation of the model relies on the accurate measurement of the required data and the establishment of appropriate incentives or penalties based on its results. On the other hand, implementing the model in the broader public road network in Chile is less feasible. This is primarily due to the significant costs involved in gathering information that is currently unavailable for these roads.

In summary, this study demonstrates the potential applicability of the proposed model in evaluating the value of rigid pavements in interurban highway concessions. Consequently, this study provides a contribution to public and private highway asset managers interested in improving the condition of their assets and service to the users. Future research could focus on the effective integration of the valuation of rigid pavements and other highway assets as performance measures in PPP projects.

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