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BIM AND DIGITALIZATION IN ROAD ASSET MANAGEMENT

A PIARC TECHNICAL REPORT

TECHNICAL COMMITTEE 3.3 *ASSET MANAGEMENT*

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2020– 2023 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were appointed by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

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EXECUTIVE SUMMARY

2023R48EN

BIM AND DIGITALIZATION

The objective of the work carried out by WG 1 within the field of BIM and Digitalization has been fundamentally to carry out an analysis of the state of the art worldwide of how Digitalization is being applied in Road Asset Management and the BIM methodology. within the same area.

From the content of the document, it can be deduced how the level of digitalization in Road Asset Management has reached a high level of technology, however, from what the reader of this report can deduce, there is still a long way to go in the application of BIM to this area. This statement is based on the results of an extensive survey carried out among road administrations in different countries and with highway concessionaires. The content of this survey can be seen in section 9.

Considering the results obtained, this document fundamentally includes a state of the art and different examples of digital applications in the management of road assets as well as certain general lines of how some of the highway agencies are directing their efforts in the coordination and preparation of certain documents that will serve as a basis for the application of BIM in Road Asset Management.

The first part of the document constitutes a guide to contextualize BIM, taking the opportunity to compile basic concepts that will serve to recognize that this methodology has a great advantage in the building and industrial sector over the application in the design of linear works and, therefore, much more. even in later phases of the life cycle of a linear work such as roads. Focusing on aspects that have to do with conservation and maintenance as the longest period in the life of an infrastructure, it can be seen, again, that there are few advances and great difficulties in applying this methodology to infrastructures designed and built long ago (they are the most road networks in developed countries and even in developing countries).

In support of strategies that can be considered by road agencies immersed in this process or that are interested in it, a series of practical cases and information on the application of BIM in the management of road assets are provided. Specifically in Spain, Belgium, Mexico, France, Japan, and Korea.

The second part of the document addresses the technological level and describes certain methodologies linked to digitalization within the field of road asset management. Examples are shown and some procedures that may be the most widespread worldwide are described. Likewise, everything described above is supported by the results of surveys of the same countries and agencies as in the case of BIM.

In the final conclusions, certain aspects of the content of the document are synthesized, the high degree of technology in the digitalization of road assets is expressed and the need to coordinate and define the dimension of BIM in this field is reinforced.

CONTENTS

INDEX ILUSTRATIONS

ACRONYMS LIST

AEC:	Architecture, Engineering and Construction sector companies
AIA:	American Institute of Architects
BIM:	Building Information Model
CAD:	Computer Assisted Design
CDE:	Common Data Environment
DEM:	Digital Elevation Models
DTM:	Digital Terrain Model
GCP:	Ground Control Points
GIS:	Geographical Information System
GNSS:	Global Positioning Satellite System
GPS:	Global Positioning System
IFC:	Industry Foundation Clasess
LIDAR:	Laser Imaging Detection and Ranging
MDM:	Master Data Management
MDS:	Digital Surface Models
ML:	Machine Learning
MLIT:	Ministry of Land, Infrastructure and Transport
NAICM:	Mexico City New International Airport
OTL:	Object Type Library
QA:	Quality Assurance
ROI:	Return on Investment
STEP:	Standard For Exchanging Product Data

1. INTRODUCTION

In the following sections of this report, we will explore the impact of the implementation of Building Information Modelling (BIM) and Digitalization on road asset management. We will analyse in detail the benefits, challenges and opportunities that these innovative technologies offer to developing countries in their quest to optimise the planning, construction and maintenance of road infrastructure.

1.1. Why to use BIM and BIM definition

A good management and maintenance of road infrastructure is based on up-to-date, complete, and reliable information about all physical terrain objects ("assets") in management of a National Road Agency. The use of BIM gives us the opportunity to efficiently collect and manage the available information over the entire life cycle of terrain objects (=assets). By collecting this information once, as close as possible to the source, and exchanging it in a standardized way, we can make the uniform data available to those who need it at any time during the life cycle, whether during the study phase of a project, during the execution of the works on site or during the management and maintenance in the subsequent period. The central AIM database must become a shared source of knowledge, which serves as a reliable basis and representation of the reality on which decisions can be made during the entire life cycle of the assets.

BIM will not only provide us with a blueprint of the roads, construction works and roadside elements, it is also a digital collaboration between all project partners within a construction project. In this way the opportunities that digital evolution offers us are embraced. It is needed to look beyond the own borders, to integrate good practices from other countries, partners, and the own organization.

Using BIM means less 'lost' knowledge. Every project partner works in the same model across all the project phases. Because of collecting and storing everything in a central AIM database, the knowledge that was gathered in the previous phase is transferred to the next. Data only needs to be gathered once and can be reused in the sequel of the project.

BIM gives us many benefits. The priority is to improve the quality of projects, but we can also count on higher efficiency during the study and on site, fewer settlements, and better information flow. That is the basis for good asset information management. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021).

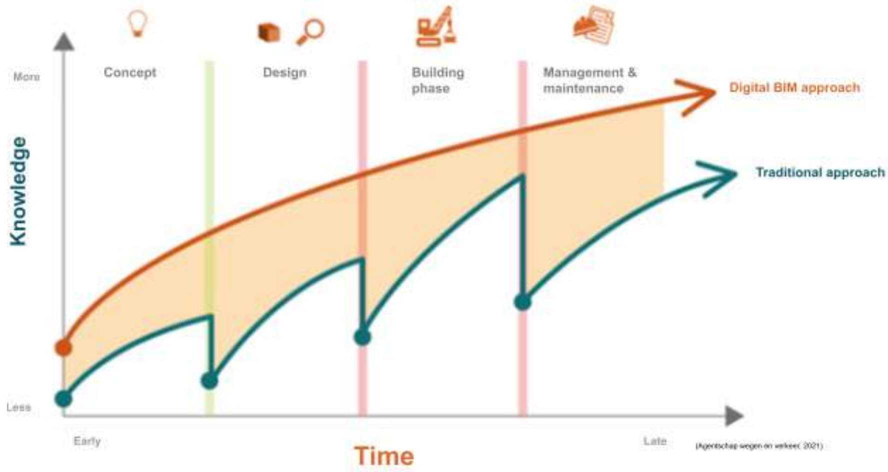

Illustration 1. Digital BIM approach versus traditional approach (Agentschap Wegen en Verkeer, 2021)

1.2. Definition

The construction industry is permanently under a digitization process. This means that the processes have been developed for centuries, such as the construction of houses or infrastructure, are evolving and the methods that were used a hundred years ago are neither they will be the same tomorrow.

This applies not only to the construction process itself, but also to design and subsequent processes such as maintenance, operation, and demolition.

If we keep it at a high-level BIM can be seen as a way of virtual road building and digital coworking on a building project between all project partners. Depending on the phase of the building project the BIM acronym can be filled in differently. There are three possible 'translations' for the BIM acronym: Building Information Model, Building Information Modelling, Building Information Management.

- 'Building Information Model' This is the digital 3D visualisation of the project in a model. This model is enriched with the information of a project.
- 'Building Information Modelling' This is the process of sharing the data between the different project partners via an exchange platform (e.g. BIM360).
- 'Bouwwerk Informative Management' This 'translation' focuses on the intelligence that is incorporated in the 3D-model. In other words: it deals with the way of managing and using the data provided in the model.

(Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

It seems to be very ambiguous for a term that claims to be the largest revolution in the history of the construction sector. BIM is a general term that describes the production processes and management of construction procedures, as well as the physical and functional characteristics of buildings, these characteristics are represented digitally. BIM is generally used to predict and control the construction procedures of the building, with the aim of minimizing the cost in terms of energy, materials, and labour. (Herr & Fischer, 2018).

Based on the current vision of the term BIM, we can affirm that it has also evolved over the years. It was in 1975 when Chuck Eastman first introduced the idea of a parametric design. Eastman intended to create the corresponding layout of sections and floors of a project from a single three-dimensional model with the help of a software; it included parametric design concepts integrated into a single database for the implementation of a visual and quantitative analysis.

In 1987, the Hungarian company Graphisoft developed Archicad, the first software capable of creating 2D drawings derived from a 3D model. Graphisoft used the term Virtual Building to describe a digital construction process, but the term Building Information Modelling BIM was first introduced in 1992 by the Delft University School of Civil Engineering. Currently the word BIM is no longer used to refer only to a parametric model, but as part of a construction process that encompasses all phases of the life cycle of an asset. (Choclán, Soler, & González, 2014).

The term *Building Information Modelling* applies to all built assets such as: bridges, highways, airports, industrial warehouses, etc. As so, the computer technology applied for the generation of data, controls, and values, and finally the models used to represent assets.

The term BIM aims to make each phase an industrial process with greater quality controls, traceability in projects, and productivity and efficiency values that can be measured. With all these new values introduced, the objective is to generate a more sustainable and efficient activity.

Due to the versatility of the industry and the time it has taken agents to adopt a specific term for the digitization of construction, it has been decided to define maturity levels and BIM dimensions. The Bew Richards BIM Maturity Model has been adopted as the most effective model to describe what is understood by Building Information Modelling, this model has been used by different associations and governments to trace development routes in the construction industry, since it contributes to the assessment of the current situation and future lines of growth and research on BIM issues. (Rogers, Heap-Yhi, Preece, Lim, & Jayasena, 2015).

1.3. DIGITALIZATION

According to Gartner (Information Technology Glossary), "Digitalization" is defined as the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.

On the other hand, "digitization", similar word to digitalization, is defined as the process of changing from analog to digital form, also known as digital enablement. Said another way, digitization takes an analog process and changes it to a digital form without any different-in-kind changes to the process itself.

In road asset management, Dr. Alfred Weninger-Vycudil (2019) describes digitalization as follows in PIARC magazine routes/roads:

"The basic principle of digitalization is a process, where information will be converted into a digital format, which can be used by computers. In the context of asset management, digitalization converts properties and characteristics of the road infrastructure assets (inventory, condition, etc.) into digital data and enables to manage this data by using asset management software tools. Digitalization is related to different tasks and linked with processes, especially in the context of data quality, management, and analysis. The benefit can be manifold but requires an efficient use of the digital information from the beginning."

Monitoring

INSAR

INSAR (Interferometric synthetic aperture radar) is a solution to measure ground deformation and structure stability from space with millimetric precision.

Based on radar satellite images, advanced processing Atlas InSAR provides millions of measurement points in areas of interest, either for construction or for maintenance activities.

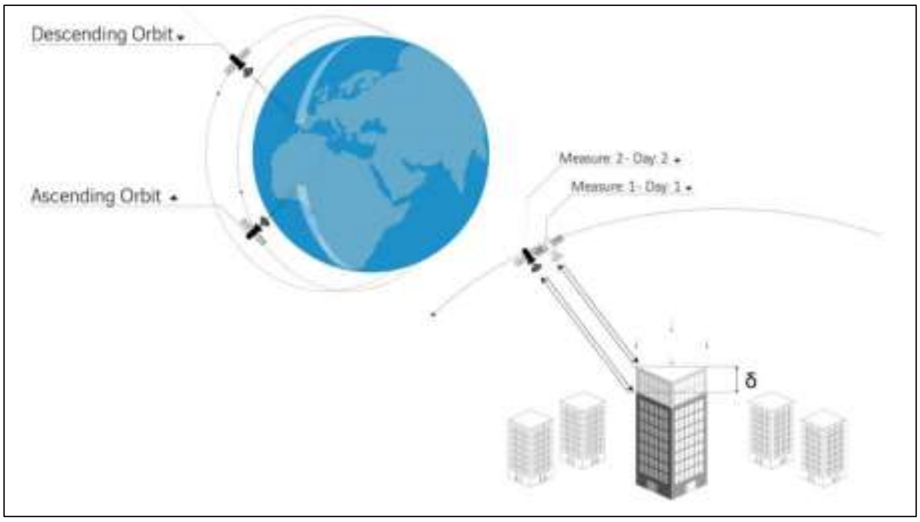

Illustration 2. INSAR technology

Radar interferometry is a Satellite remote sensing technique which is capable of measuring millimetric motion of terrain over wide areas.

Interferometric synthetic aperture radar (InSAR) involves the use of two or more synthetic aperture radar (SAR) images of the same area in different moments of time to retrieve landscape topography and associated deformation patterns.

A classification of measurement points is applied to be able to read deformation values in an easy way. Usually, cool colors (blue) are used to represent movements towards the sensor (usually uplift) and warm colors (red) are used to represent away from the sensor (usually subsidence), while green color states stability of the terrain. An example could be these two different legends are applied where the parameters to be classified are cumulative deformation (mm) and velocity (mm/year).

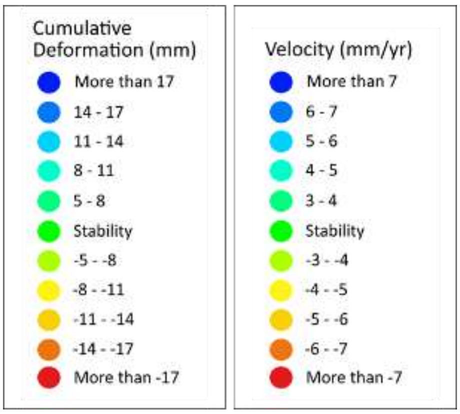

Illustration 3. Classification of measurement points

Structural Health Monitoring (SHM)

Structural Health Monitoring (or SHM) uses permanently installed sensors to generate continuous data. A specific software enables to display the data in smart graphics and generates alerts. It is used in conjunction with spot check inspections to enable relevant structural data analysis. Its aim is to maintain infrastructures, extend their working lives, and detect and forecast their faults

Traditional monitoring

Monitoring involves the observation and analysis of a system over time using periodically sampled response measurements to monitor changes to the material and geometric properties of engineering structures such as bridges and buildings.

Ground/slope

Earthworks, special foundations, and subsurface contracting inevitably involve ground-related deformations that must be monitored.

Using geotechnical sensors to carry out this task provides control of geotechnical risks and can contribute input to the process of optimizing the dimensioning of subsurface structures.

Sensors installed during the earthworks project can be retained for long-term monitoring of cuttings and embankments, for example.

Geotechnical sensors are also useful for monitoring soil movement in terms of landslips, settlement, etc. They also contribute to causal diagnostics, deconsolidation risks and identifying any reinforcement work that may be required.

Environmental

Human activity and construction work, generate environmental pollution, such as noise, vibration, and dust.

Monitoring these and other similar forms of pollution makes it possible to control them more effectively to reduce their impact on local communities and the wider environment.

Environmental monitoring also has a role to play in protecting biodiversity.

The purpose of monitoring emitted noise is to control the acoustic impact of a construction worksite or installation relative to ambient noise levels, and to check the actual level of noise in nearby dwellings, for example.

Noise sensors can also be used to detect the presence of land and/or aquatic animals. Acoustic monitoring can therefore be a useful tool for conserving and protecting wildlife during work on site.

For example, vibration monitoring can be used to check the level of vibration caused by worksite plant and machinery and its propagation over a given distance. It is also an essential tool for protecting buildings or infrastructures that are sensitive and/or contain their own measuring instruments, such as hospitals, rail traffic control centers, manufacturing plants, etc. This type of sensor is also used to provide long-term monitoring of structural vibration modes and amplitudes.

In urban communities, it is essential to control dust levels and air quality. The sensors required to make these measurements are usually installed as part of complete weather stations.

In the great majority of cases, water and soil pollution measurement is required because of human activity, either current or – in many cases – past.

IoT

The Internet of things (IoT) describes physical objects (or groups of such objects) with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks.

Business Intelligence

Business Intelligence (BI) is an umbrella term for a range of technologies, processes and tools, as well as best practices, that enable large amounts of data to be collected, processed and analysed to generate useful information. All this in order for end users to access better information that they can use for further decision making.

For our case, we will focus on it as management tools, which are those whose main purpose is to store, centralize, structure and distribute data within the same business. These are vital for the analysis of variables and factors.

Inspection

Digital inspection.

An inspection is a surveillance action, which establishes a health check of a structure, based on a visual assessment of its condition. The digital inspection consists of making an integral survey of a structure using digital sensor, either remotely or closely, in order to detect the presence of disorders and make a judgment on structural health.

Illustration 4. Courtesy of Sixense

Digitized inspection in the field has evolved over time, until specific applications integrated with management systems have been developed, which allow automatic synchronization from the field, exporting the information to the management system itself in seconds. This synchronization requires an internet connection, but also allows the information to be managed and transferred when the device can be connected to the network.

Illustration 5. Data collection with a telephone device of the assets on the road.

Having a powerful device that stores information and allows the management of incidents occurring in the field, as well as scheduling work overtime or monitoring road sections, is important for proper operation. The working methodology consists of data collection in the field in conjunction with synchronization with the office management system available.

There are other more complex methodologies for data acquisition and processing in the office, such as drones or lidar equipment. These have been gaining ground in the sector for years, being the most attractive option for the detection of road assets on a continuous basis, but not for their detailed status review. Data collection with this type of device involves a post-process of verification and quality control, as their reliability is not 100%.

The LIDAR process involves the collection of data with a specialized vehicle, as well as the subsequent process of detecting elements. These will be geopositioned with high precision thanks to the tools integrated in management systems, which allow measurements, distances, asset location and others to be measured on images.

For daily monitoring of road conditions, this process using LIDAR is neither agile nor operational, as it requires powerful and costly instrumentation. The same applies to drones, which are also subject to regulatory obstacles for data collection as they invade airspace and are not usually allowed in areas such as airports.

In view of the above, it is safe to say that, at present, the most reliable system for carrying out high quality inspections of assets are apps that can be installed on mobile phones, tablets, or robust devices for taking data in the field.

Road inspection.

In addition to the inspections mentioned in the previous point, other options are available on the market for more specific points. The treatment of the condition of the pavement from the point of view of cracking, through the calculation of the PCI value (pavement condition index), applications aimed at emergencies arising on the road, or the processing of data through Big Data analysis.

- Cracking-IPC. Pavement inspection from the point of view of surface deterioration involves the collection of data by different methods. Whether manually or continuously, with high-performance equipment, the condition must be unified, always considering the subjectivity of certain methodologies as well as the faults produced by the automatic detection of certain monitoring equipment. For this purpose, the PCI parameter is considered, by means of deterioration weighting formula.

The PCI, which quantifies numerically, gives us the condition of the pavement. The PCI varies from 0 to 100 depending on the pavement deterioration as can be showed in the following illustration.

Illustration 6. PCI classification

It can be found three different stages according to the actuation needed: maintenance, rehabilitation, and reconstruction.

It is not a fine-tuned method for detecting failures, it is a method to evaluate the superficial state of the pavement and the consequent action and but a methodology for defining areas or sections where it is most urgent to act, according to the type of failure found.

The PCI varies from 0 to 100 depending on the pavement deterioration.

Even this method does not give an idea about the necessity, or not, of structural state, a low value of PCI shows the high possibility of a structure failure.

For data collection, equipment such as the LCMS provides dynamic data collection and subsequent automatic processing using the parametric software. The procedure consists of recording pavement lines covering the entire lane.

Illustration 7. Data collection

Once the information has been dumped into the support software, it is processed, and the surface deterioration detected by the laser equipment is obtained.

As has been mentioned, the fine-tuning of the result to reality involves a post-process of revision and verification of the deterioration detected, to avoid shadows or water marks as well as other faults in the image that do not correspond to deterioration of the pavement as such.

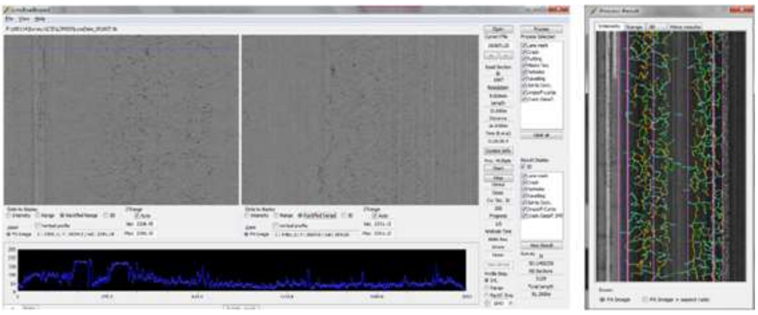

Illustration 8. Data obtained.

- App-SOS. To deal with incidents such as accidents on roads, Rauros has the SOS APP, which allows the user to download and subsequently use it, providing an extra to the applications that road maintenance may have. In this way, the user is a participant in the state of the road and speeds up the resolution of incidents.

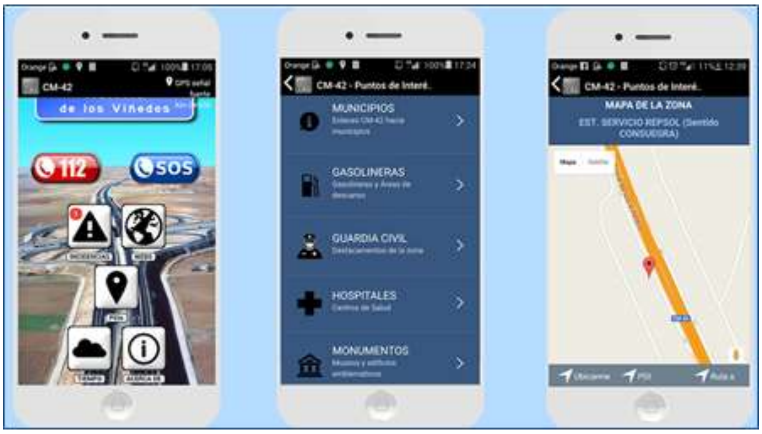

Illustration 9. APP-SOS.

The objective of the implementation of this application is to replace the SOS posts, which have been practically abandoned with the appearance of mobile phones, and in addition to providing user support, to give feedback to the person in charge of road maintenance on the incidents that occur.

1.4. MACHINE LEARNING PROCESS

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves.

The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly.

The orthophoto images are carefully screened and downloaded to cover all the required regions containing the road data.

The following flow diagram shows the flow of the data preparation process.

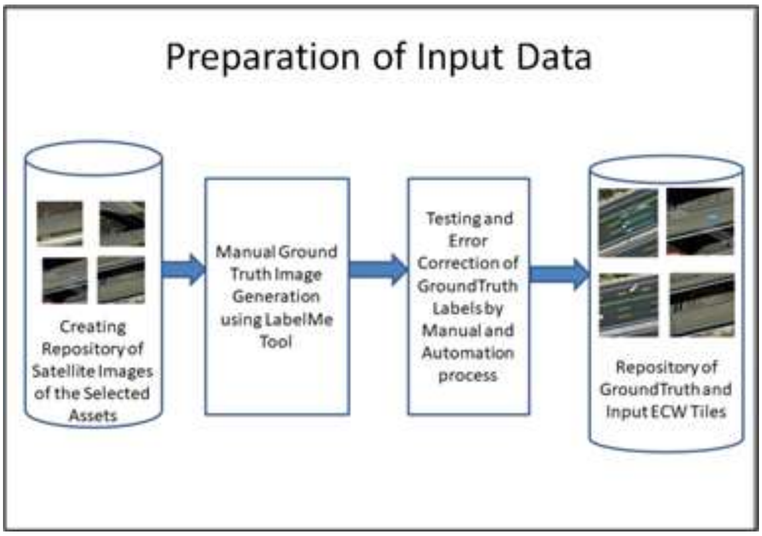

Illustration 10. Preparation of input data

The data is prepared in different methods for the various type of road markings such as:

Linear Road Markings

Linear Road markings are continuous markings on the road depicting the different aspects of lane separation and the output requirement for these markings from the ML model is to mark the position of the occurrence of these lines with a tight bounding box.

Area Road Markings

Area Road Markings are the markings for which the ML model has to not only detect the position of the asset with a tight bounding box but also compute the area occupied by the asset.

Point Road Markings

Point Road Markings are the markings on the road that are not continuous in nature. The output requirement for these assets from the ML model is to detect the type of asset, the position of occurrence of these assets and then compute the centroid of the object.

Initial experimentation was performed with Semantic segmentation model to detect these assets, but they did not give good results due to data insufficiency and hence Object detection model was proposed for detection of these assets.

Each of the point asset is marked with a rectangular bounding box and tagged with the label types as Straight arrow/Curved Arrow etc. The Yolo model will be trained with the coordinates and the corresponding label to detect the position and type of asset.

The below diagram shows the typical Architecture of ML

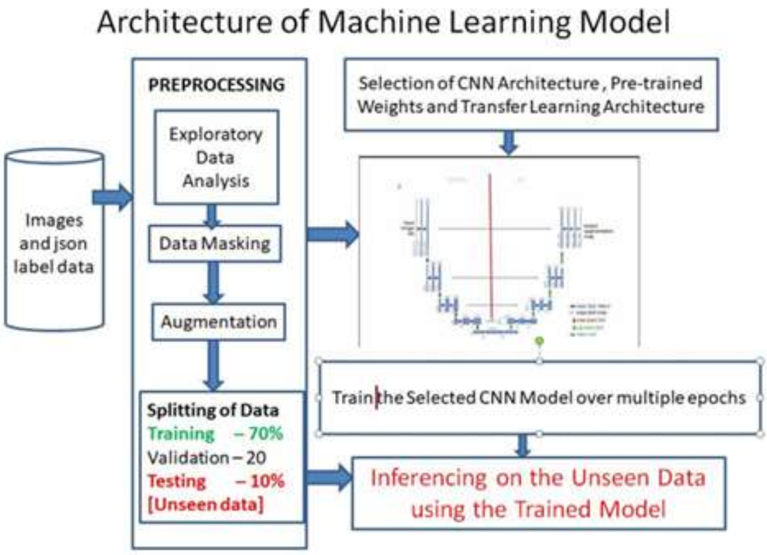

Illustration 11. Architecture of Machine Learning model

The ML model shall be post processed using Geospatial techniques available in PostgreSQL, Quad tree, curve fitting methods, converting pixel to world geometry & other tools.

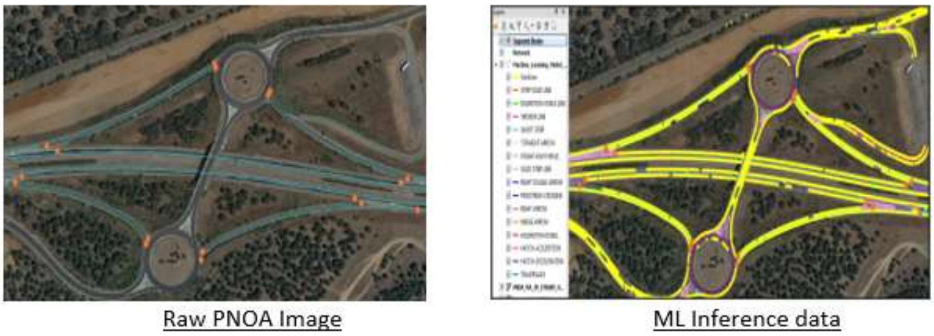

Illustration 12. Machine Learning inference data

Overall, the semi-automatic process is 4 times faster than the manual method. While the performance per kilometer in the manual method is approximately 3 hours/km, the semi-automatic method, once the machine has learned the corresponding learning process, reaches 4 km/hour. In networks or roads with a considerable number of kilometers there is no doubt that the semi-automatic method compensates with respect to the times mentioned, but in cases of smaller roads it would have to be studied as the learning time of the machine may not be able to compete with the manual performance.

1.5. ASSET MANAGEMENT

Asset management is a framework leading to improved management of infrastructure assets and improved decision making based upon quality information and decision making. It needs to be stressed that asset management is not a computer program, nor is it a rigid protocol. It is a set of business processes for decision making that encourages continuous improvement in infrastructure management. Asset management provides a road organization a framework to communicate its approach to its workforce, to external stakeholders including politicians, to the media, to its external partners and to the public. (Agentschap Wegen en Verkeer-Agency for Road and Traffic)

1.5.1. Why should we do it?

The traditional way of doing business, in which we wait to repair our assets until they are broken, is no longer sustainable. It is too expensive, and it erodes the value of these important assets.

Therefore, we should search for a more sustainable approach. An approach that sets us in place to monitor the whole life cycle of an asset. Starting from the initial need, through the design, over the execution, maintenance and ending up in archiving.

Like that, we always know which assets we must manage and maintain, in which condition they are and what actions we need to take. (Agentschap Wegen en Verkeer-Agency for Road and Traffic)

1.5.2. Technical Prediction (Ageing Models, Decision Trees…)

Predictive models are defined as a group of techniques that, through the fields of machine learning, historical data collection, Big Data and pattern recognition, aim to provide a prediction of future results. All this, with the aim of refining decision-making by means of data analysis techniques.

If we focus the definition on the field of infrastructure maintenance, predictive models should contain information on road assets in detail and thus be able to obtain an adjusted schedule of the activities to be carried out and the investment they will require. This necessary information is difficult to obtain depending on the asset whose behaviour is to be predicted.

The most studied road asset in this field at the present time is the pavement, of which various information is known regarding the materials of which it is composed, the circumstances which affect it (the origin of its materials, the climate, its foundations, the traffic it supports...), and in addition, it is under continuous observation by means of auscultation by different methods and instrumentation.

For all these reasons, there are various methodologies for predicting the evolution of the pavement, both in terms of its bearing capacity (related to its useful life), and in terms of the surface quality of the pavement, which is closely related to road safety and comfort on the road.

However, current models cannot be generalist, since, as has been mentioned, the circumstances and characteristics of the pavement are numerous and can be highly influenced in each case.

In this sense, the evolutionary models of pavement deterioration (service life) are still an unknown quantity and something very subjective if we want to obtain models which can be replicated on a variety of roads with different and diverse circumstances.

The theory regarding pavement deterioration is well known, considering that it always follows a degradation curve with the same trend regardless of the characteristics of the environment and the pavement itself. However, it is difficult to obtain numerically, in time, the deterioration milestones of a pavement due to the infinite number of circumstances associated with it.

The following image is an example of an evolutionary model of the IRI parameter. In this image, taken from a road asset management system, 3 curves can be seen on the left, representing the real curve generated by the auscultations over the years, the exponential curve expected on the basis of these auscultations, and finally the steepest curve, relative to another pavement analysis system. On the right-hand side, the point monitoring values of the study segment can be consulted. This allows a detailed analysis of each sub-segment, its historical and current conditions, as well as an idea of its future evolution and, therefore, of the investment it will require in the coming years.

Finally, it is usually decided to analyse the evolutionary models of the pavement monitoring parameters, as they provide the largest number of records and allow for their analysis. These parameters are usually: IRI, CRT and deflection. Others, such as cracking or rutting, depend on several factors that make it difficult to obtain an adjusted model curve. Regardless of the latter, for any parameter, the best evolution curve that can be obtained is the one generated from the pavement monitoring history, without interventions, and thus to be able to know the speed of deterioration of the parameter and therefore of our pavement.

In a pavement management system, decision trees are known as such in a pavement management system, the assignment of actions on the pavement, depending on the failure of one or several parameters. All of this is conditioned by the action priorities of the road maintainer and the service levels (quality standard) of the parameters in question. In a simple way, if a homogeneous segmentation of roads is available, the management system should contain the following conditions for a correct application of the decision tree. For each homogeneous sub-segment:

- Pavement type
- Traffic carried
- Parameters monitored over time
- Failure threshold for the parameters
- Actions or repairs with costs associated with each of them
- Type of repair as a function of failure
- Possible failure combinations

Table 1. Parameter combination matrix

Combinación	Parameter		
	IRI	FISU	DEFL
1	0	0	0
2	0	1	0
3	0	0	1
4	1	0	0
5	0	1	1
6	1	0	1
7	1	0	0

Finally, in a schematic way, a matrix/table as shown below will be obtained.

Table 2. Failure matrix

Sub-segment	Failure (1=Yes)		
	IRI	FISU	DEFL
T-1	0	0	0
T-2	0	1	0
T-3	1	1	1
T-4	1	0	0
T-5	1	1	0
T-6	0	0	0
T-7a	0	1	0
T-7b	1	0	0

1.5.3. Financial Optimization

Just as important as keeping infrastructures in optimal conditions is being able to adjust the available budget. By prioritizing actions according to the budget, as well as the criteria mentioned in point 5.5, a management system must allow different investment scenarios to be carried out to combine the correct maintenance and the optimal and necessary investment.

A Road Asset Management System makes it possible to analyze, by homogeneous sections, the investment based on certain criteria, such as the cost of the actions, the annual price increase of the same, as well as the financial criteria of the entity responsible for the maintenance of the infrastructure. This means that, although a fixed annual allocation may be made, there will be cases in which the investment will be one-off and of a large amount, in which case it will be necessary to bring forward actions that may be left unattended. These, or other cases, can be assessed in a road asset management system, as discussed below with examples.

In the following case, the study has been carried out on the basis of the needs of the road, i.e., the direct application of evolution of monitoring parameters, quality levels required by the road maintenance company, and actions associated with the faults with their costs by units of measurement. All this implies a 5-year investment of almost 29 million euros.

The colors of the columns indicate the actions that are recommended to avoid failure (green), those that are mandatory (red) because the value of the parameter or parameters has already failed, the total of both per year (yellow), and finally the adjustment to a budget required by the manager (blue). In this first example, the amount of the mandatory actions is applied in this adjustment.

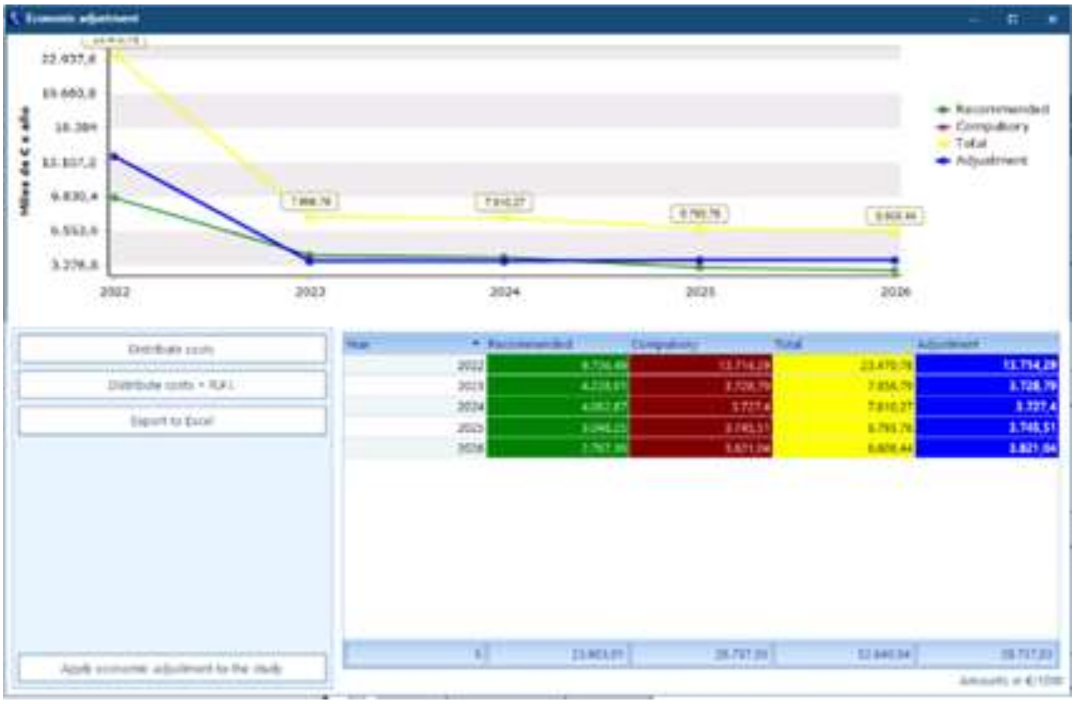

Illustration 13. Different investment scenarios to be carried out.

In the second case, the manager has set the adjustment (blue) to its estimated annual budget.

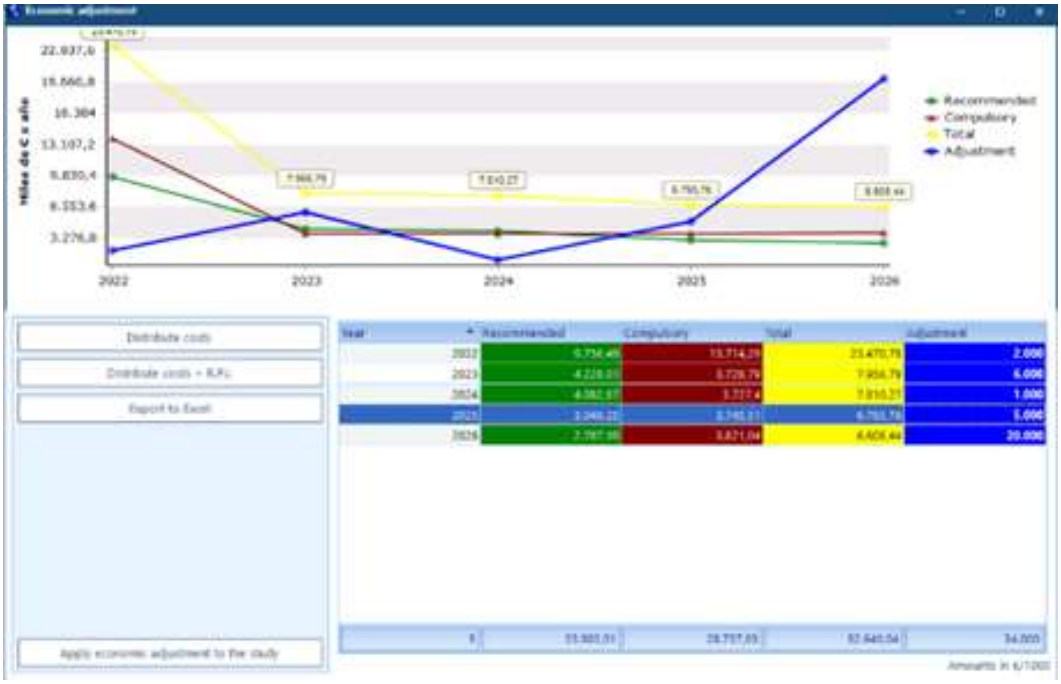

Illustration 14. Different investment scenarios to be carried out with the adjustment to its estimated annual budget.

1.6. CONSTRUCTION SITE MANAGEMENT

The Construction site management with BIM ("Bim-to-field") refers to the transmission of digital planning data to the construction site. This minimizes planning risks and avoids sources of error. The advantages are undeniable: correct execution of the construction site and a clear increase in the efficiency of the projects, not to mention a contribution to the improvement of work safety that should not be underestimated.

The following figures compares between the conventional construction work and the construction work using BIM and ICT (Information and Communication Technology). The former is labour-intensive, time-consuming, and weather-depending work. On the other hand, the latter becomes high productivity work by introducing BIM and ICT.

Illustration 15. Conventional construction work and construction work using BIM

In the survey and 3D design drawing, the effects are

- Laser irradiation over a wide area can shorten the process by performing surface surveying.
- Automatic calculation of soil volume is possible from the difference between the acquired three-dimensional point cloud data and the three-dimensional design data.
- By using three-dimensional point cloud data, visual understanding of structural shape, surrounding environment, and topographical can be possible.
- The above leads to make the optimal construction work plans including the selection of heavy machinery.

However, there are a few problems at this stage:

- Smaller scale of construction is less effective and less cost-effective.
- There is the lack of human resources and equipment for handling three-dimensional data.

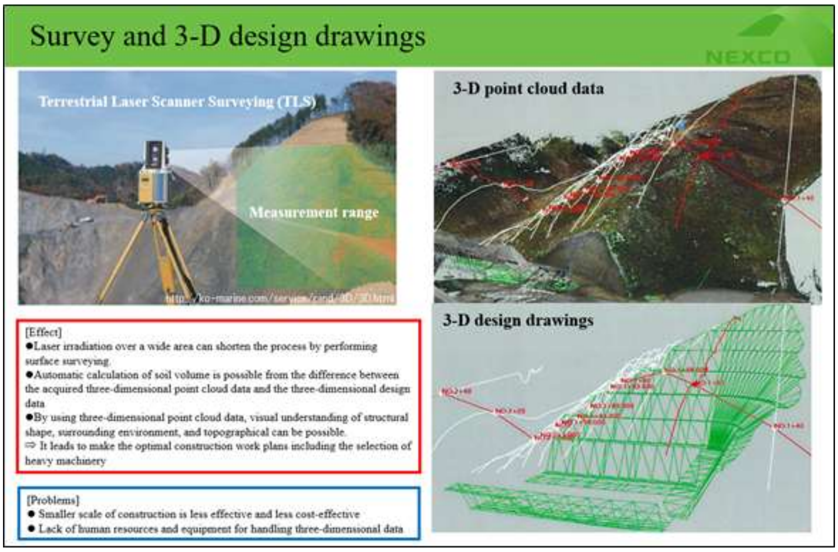

Illustration 16. Survey and 3-D design drawings

By applying BIM and ICT, it can be possible to use construction machine equipped with machine guidance. Machine guidance displays as-built drawings to be constructed and the position of the cutting edge on the monitor screen of the cockpit of the construction machine. The cutting edge on the monitor screen and the actual cutting-edge position are linked by GNSS (Global Positioning Satellite System), and the movement of the construction machine is reflected on the monitor screen. The operator can operate the construction machine while checking the guide on the monitor screen.

The advantages are:

- It can be possible to reduce the number of finishing stakes to be installed as mark for construction.
- Machine guidance equipment can be retrofitted to existing construction machinery.
- Machine control hydraulically controls the construction machine to prevent it from digging deeper than planned.
- Even an inexperienced operator can operate it. By performing operations that previously required experience at an early stage, you can acquire a sense of construction in a short period of time.
- However, the problem is that there is a time zone during which the positioning satellite cannot be captured.

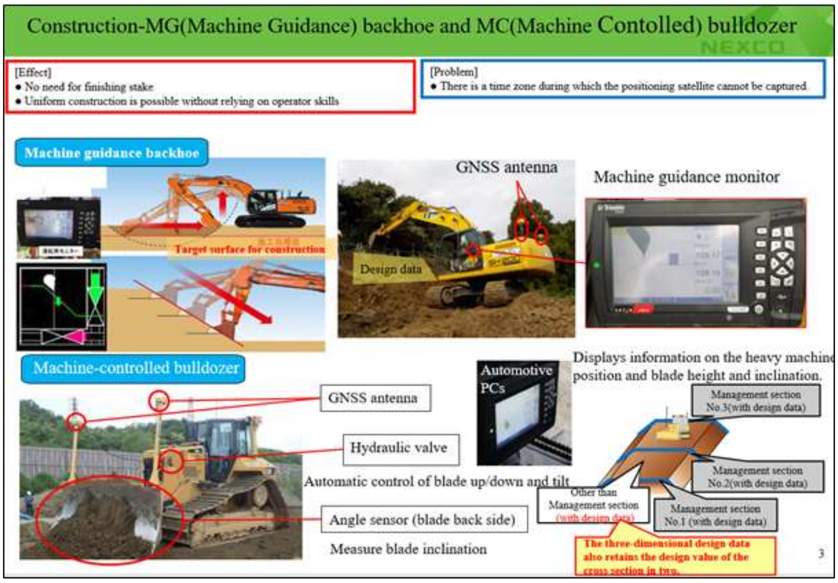

Illustration 17. Construction- Machine Guidance Backhoe and Machine Controlled Bulldozer

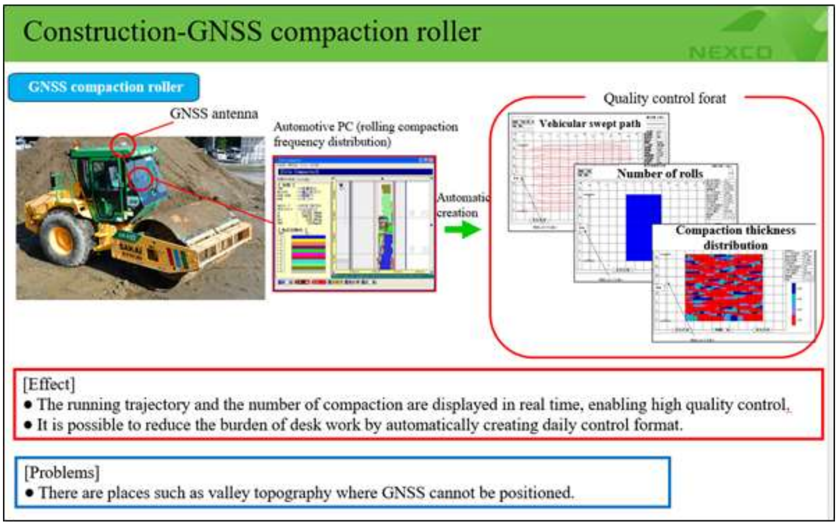

Illustration 18. Construction- GNSS Compaction Roller

The following advantages of construction work using BIM can be enumerated:

- Drawing. In steel bar arrangement drawing, the bars interfere with other bars. The difficult parts to be assembled can be confirmed beforehand, thereby rework can be avoided.
- Mechanic Management. The use of mechanical joints instead of gas pressure welded joints eliminates the need for skilled workers. It is possible to reduce working days by speeding up bar arrangement work.
- Safety Management- Laser Barrier. The machine operator can get the alarm directly at the driver´s seat when the machine is close to the structure and labors. It can reduce the number of safety patrols.

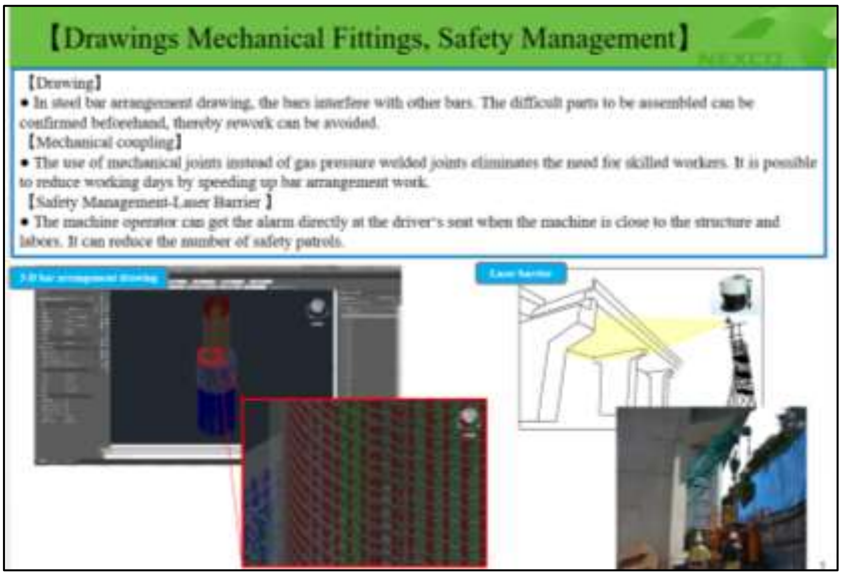

Illustration 19. Drawings, Mechanical Fittings and Safety Management using BIM

In the centralized management of measurement information during tunnel construction, the following advantages can be obtained by introducing BIM.

- Integration of construction information (automatic measurement) along with 3-D design facilitates on-site management and reduces desk work.
- The omission of on-site inspection of lining thickness is possible through management of measurement data at each construction stage.
- The accumulated initial tunnel data is utilized for maintenance and management such as inspection.
- Measurement data is centrally managed, and when the control standard value is exceeded, alarm mails are automatically sent to the parties concerned.
- Examination of a database for use in maintenance and management.

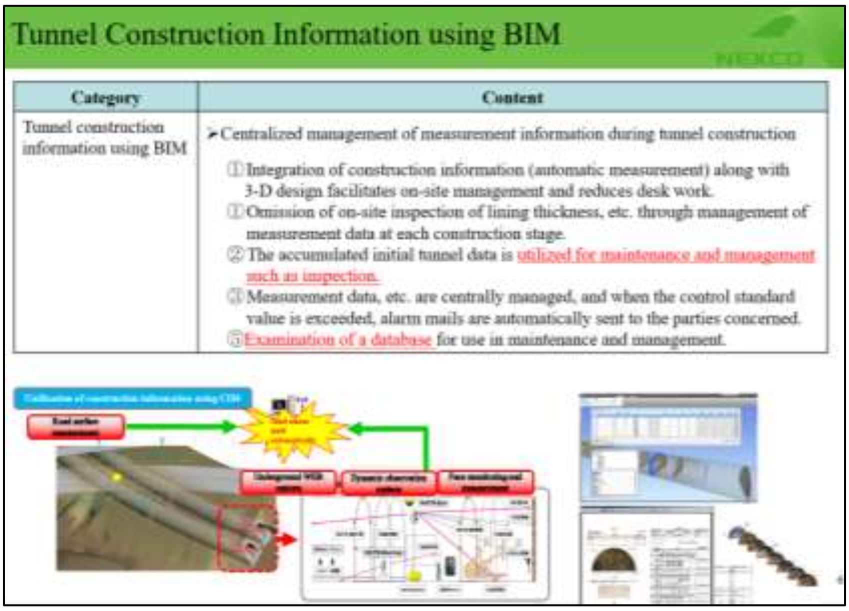

Illustration 20. Tunnel construction Information using BIM

1.7. THE OTL AS A DATA STANDARD FOR BIM AND ASSET INFORMATION MANAGEMENT

Besides the general rules on how BIM can be implemented, there is one major requirement for being able to do Master Data Management: an uniform way for collecting data via BIM. Therefore, an Object Type Library (OTL) can be built.

1.7.1. Definition

The Object Type Library (OTL) forms the basis for the BIM models that are built up during the study and execution phase of a project. The OTL is a data standard that provides a common language to speak with all the project partners. It is a standard that is both machine and human readable. Like that everyone understands the same when speaking about a certain asset. And the data, incorporated in the BIM-models, are structured in the same way, so every machine can interpret the data the same. This makes that there are no semantic discussions possible.

The OTL describes which types of objects/assets exist, which are the attributes of each object type that we want to know and what the possible relationships are between those objects. Several workgroups of specialists on specific assets have come to consensus which data needs to be gathered in order to come to a performant AIM. For example: for a traffic sign post possible attributes we want to know could be mounting, width, diameter, manufacturing instructions, length, length above ground, length underground, type, wall thickness.

The OTL is genuinely speaking a data model that is built by atomic parts i.e. the objects. These atomic parts can be aggregated to installations. for example: the camera is an installation, the lens is an atomic part. This makes it possible to inspect assets on different levels.

Every atomic part that is incorporated into the OTL is equally important. In other words, the OTL is a flat data model, in which the atomic parts can be linked to each other by means of relationships without one part being more important than the other. This approach makes it not possible to create hierarchical structures and makes it much easier to maintain the OTL because only one element needs to be adjusted. Combined with the central supervision in one OTL team, makes the OTL is easy to maintain. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

1.7.2. ADVANTAGES

In short there are three main objectives for standardizing our assets. First, as already said, it sets us in place to communicate in a common language with all our project partners. Semantic discussions are excluded because every object has its own definition, attributes, and relationships to other objects. Second, because of the machine-readable aspect of the OTL, data is standardized. This enables us to store and reuse the data in an efficient way. And third, the OTL also helps the infrastructure sector itself. Coworking between the different project partners will be a lot easier due to the uniform approach. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

2. OBJECTIVES

This section will name the main objectives guiding this study, highlighting the importance of applying innovative technologies to improve efficiency and sustainability in the planning and maintenance of international road infrastructures.

- Investigate the use of BIM (Building Information Model) and Digitalization, by using a standard format, in conjunction with current AMSs used by road owners and operators to implement in Asset Management
- To obtain a general level of knowledge and application of BIM technology in road asset management.
- Achieving a world-class level of digitalization in road asset management.
- To establish a working model in BIM and Digitalization to be applied in road asset management based on best practices.
- Transfer knowledge and case studies to PIARC´s road asset management handbook.
- Analyze the current situation of BIM and Digitalization in LMICs.
- Take into account works carried out by T.C.D.1 – Asset Management within Cycle 2016-2019.
- Improve and innovate managing assets approach by taking into consideration of a triple bottom line of sustainability (PPP, i.e. profit, people, planet).
- Encourage coordination with other TCs and TFs, such as T.C. 1.1 – Performance of Transport Administrations, T.C.1.2 – Planning Road Infrastructure and Transport to Economic and Social Development, T.C. 1.3. Finance and Procurement, T.F. 1.2 – HDM-4, T.C.2.4 – Road Network Operation/ITS, T.C. 4.1 – Pavements, T.C. 4.2 – Bridges, T.C. 4.3 – Earthworks and T.C. 4.4 – Tunnels and T.F.3.1 – Road Infrastructure and Transport Security

3. METHODOLOGY

The methodology followed to carry out this project could be structured by naming some of its activities:

- Periodic meetings between the members from the Working Group in order to share ideas and comment on the progress made.
- The members from the Working Group discussed possible examples of the topic in their countries of origin.
- Exploring the different challenges and solutions that are being or can be adopted by road administration in both HICs and LMICs.
- Literature review, and identification and development of case studies.
- Conducting surveys and assessing the results of these surveys.

In the following sections you will find detailed surveys and case studies, together with their results.

The division between BIM and Digitalization has been considered as two large blocks of work and, for this reason, the document includes this division in its content in its sections.

The content and the results that have been obtained following the methodology indicated in the points described above are detailed below in different sections.

3.1. MEETINGS

Throughout this work cycle, different meetings have been held in which a roadmap has been drawn up in order to organize and efficiently carry out the report. The common ideas of each of the members of the group have been put on the table and different changes or solutions have been explored that could be carried out in the different places in order to improve with this technology.

The following table shows the meetings held for the preparation of this report.

BIM AND DIGITALIZATION IN ROAD ASSET MANAGEMENT			
2020	2021	2022	2023
4	3	1	0

3.2. CASE STUDIES

Section 6.3 reflects the various case studies conducted for this report. It has been considered easier for the reader of this document to integrate them together with the surveys and their results. Specifically, the following case studies have been considered, only one of which corresponds to a LMIC (Mexico):

- Spain
- France
- Mexico
- Belgium
- Japan

- Korea

3.3. CURRENT SITUATION. BIM IN THE WORLD

An international survey was conducted to assist in understanding the current status of BIM implementation and use in the world.

3.3.1. International Survey

The development of 3D models began in the 1970s and there is no doubt that the definition of BIM, its design parameters, dimensions, and characteristics have evolved over the years. In order to define the parameters and design conditions of a project, it is important to know the international scene, its development in recent decades and the organizations that help regulate improvements to support the exchange of information between different platforms, reduce costs, improve the quality of information and help environmental performance with new technologies.

The implementation of BIM methodologies has grown very rapidly, mainly driven by private owners and government agencies that are interested in institutionalizing the benefits of BIM. Project owners who have taken advantage of BIM technologies have been able to meet and exceed the objectives defined by the implementation plans in their respective countries, resulting in a considerable increase in users of these new technologies. An example of this is the increase in contractors that reported the use of BIM technologies in North America from 28% to 71% between 2007 and 2012. Like North America, the market for BIM platforms in the United Kingdom and other regions has increased drastically thanks to the fact that most contractors report a positive Return on Investment (ROI). (The business values of BIM for construction in major global markets, 2014).

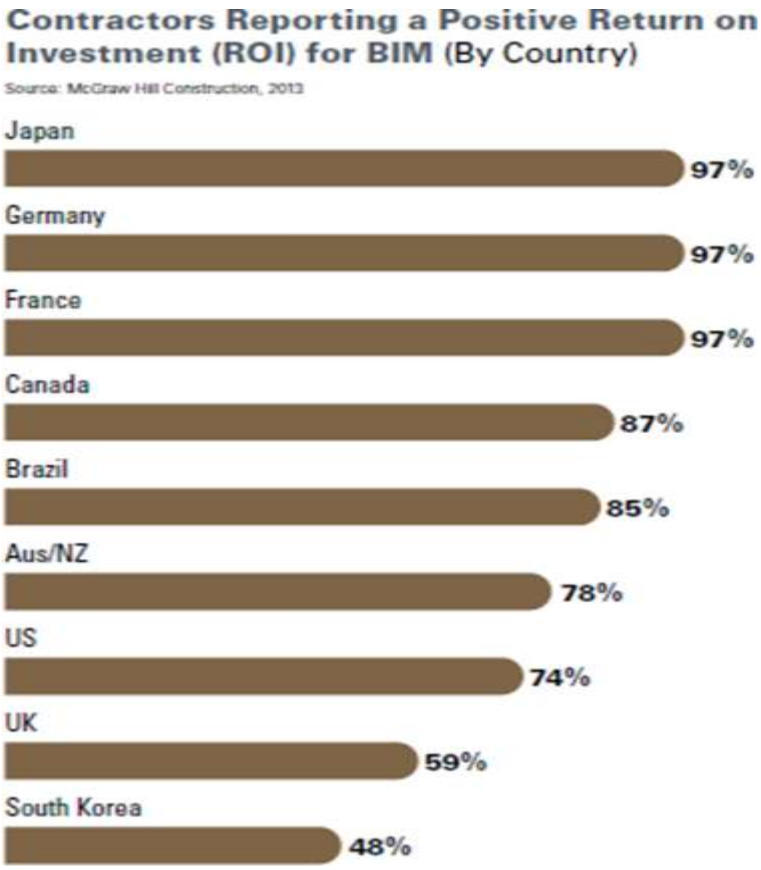

Illustration 21. Positive Return on Investment (ROI) for Contractors

Due to its objective of improving cost, value, and environmental development using BIM technologies, the BuildingSMART Alliance is one of the most important organizations worldwide, in addition to supporting the development of various BIM programs at the international level and being in charge to develop and maintain the Industry Foundation Class (IFC) platform, which favours the interoperability of models from different platforms.

Currently there are 18 BuildingSMART chapters around the world, among which are: Spain, Canada, Australasia, Benelux, France, Germany, United Kingdom and Ireland, China, Italy, Japan, Korea, Malaysia, Nordic countries (Denmark, Finland, Sweden), Norway, Singapore, Switzerland, and the United States. The objective of these chapters is to measure the level of BIM maturity in each country and to help develop policies for BIM adoption.

Thanks to the work of the European Committee (CEN / TC 442) the adoption of the first three European BIM Standards has been achieved, which are:

- EN ISO 16739: 2016 Industry Foundation Classes (IFC) standard created for the distribution of information in the construction and facility management industry.
- EN ISO 29481-2: 2016 Delivery formats for BIM models.
- EN ISO 12006-3: 2016 Organization of information for construction models (Hore & McAuley, 2017).
- ISO 19650 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling (ISO 19650-1:2018).

3.3.2. Results of the survey. “are you currently working with BIM?”

Today, about 25% of the respondents are already working with BIM. Another 50% is willing to work with BIM. Especially in Europe, BIM really starts off, 10 out of 18 countries say they already work with BIM, 4 countries say they would like to work with it. In Africa on the other hand, not a single country is currently working with BIM, but they are almost all willing to.

About 20% of the respondents stated that they are unsure if BIM is useful for their organization, while about 4% states it’s not useful for them.

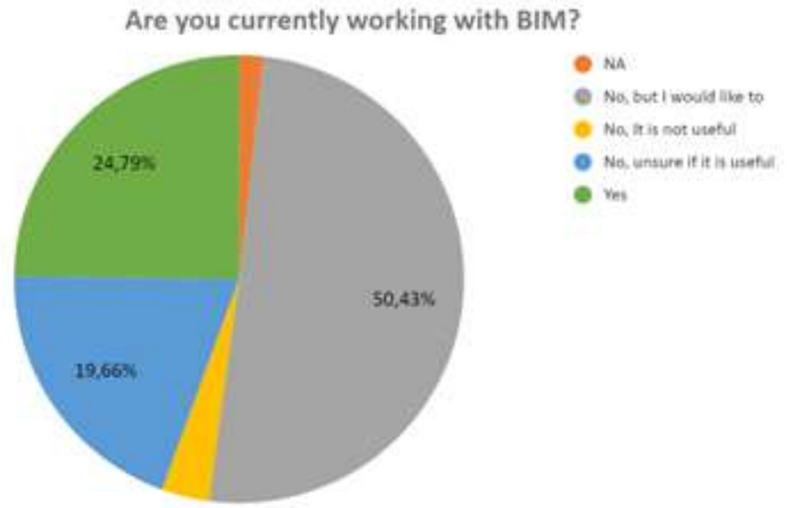

Illustration 22. Survey results “currently working with BIM”

Different respondents of the same countries have given different answers on yes/no questions… A possible explanation for this is that there are various Road Agencies for different regions in the countries.

Recommendation: Various countries have already acted on BIM; however, it’s not everywhere coordinated. We recommend the highest authority (National/Federal) to take the coordination at national level and support the regional/local authorities in implementing BIM in a standardized way.

If we take a closer look at the sector, we see that BIM is more popular in the public sector than in the private sector. 69% of all respondents which answered with “yes” are working in a public sector organization.

Conclusion: BIM is more used in the public sector compared to the private sector.

About 57% of the respondents represented a public sector organization, so the results can be biased.

If we take a closer look at the number of employees within an organization, we see that BIM is more popular in the bigger organizations with >1000 employees. 62% of all respondents who answered with “yes” are working in such a big organization. On the other hand, we see that small organizations are reluctant to BIM and don’t always see the advantages of it.

Conclusion: BIM is more used in big organizations (>1000 employees) compared to smaller organizations.

In most of the countries, BIM is in the preliminary introduction stage.

The government, academics professionals and concerned consultants have been implementing trial projects, preparing technical standards, standardizing procurement norms, and coordinating training materials. But the above procedure is a costly and time-consuming process. Therefore, at this stage, the public sector is more involved in BIM, compared with the private sector. Also, larger organizations are more involved in BIM, compared with smaller organizations in the road sector.

3.3.3. Results of the survey. What do you know about BIM?

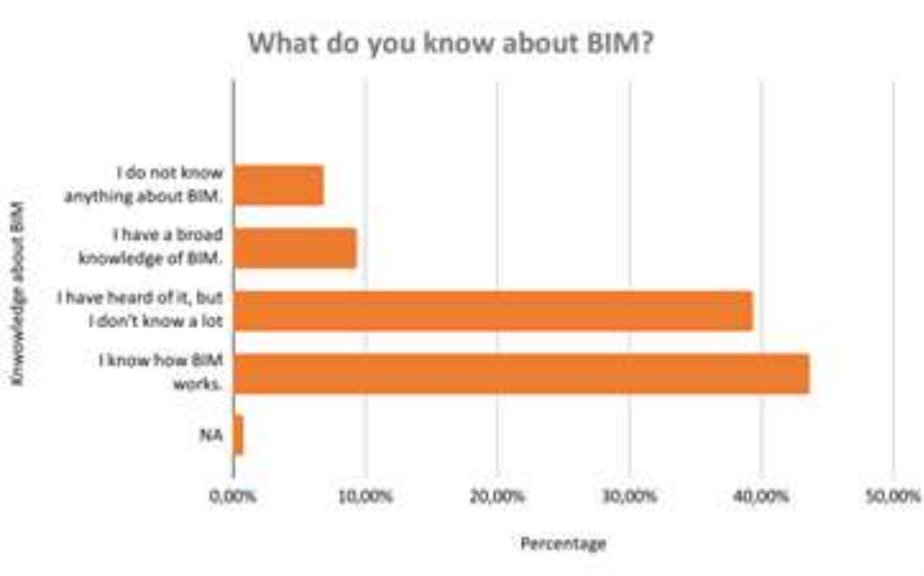

Illustration 23. Survey results "What do you know about BIM?"

When asking "what do you know about BIM?" Less than 10% of the respondents don't know anything about BIM, and about 39% have heard of it, but don't know a lot about it. That means that about 46% of the respondents do not have enough knowledge to start working with BIM. On the other hand, about 44% know how BIM works and about 10% state to have a broad knowledge of BIM.

Conclusion: BIM is already known, but there is much room for improvement

If we take a closer look at the sector, we see that public sector respondents have a broader knowledge of BIM compared to the private sector respondents. 63% of all respondents who answered with "I have a broad knowledge" are working in a public sector organization.

Conclusion: BIM is better known in the public sector compared to the private sector

About 57% of the respondents represented a public sector organization, so the results can be biased.

If we take a closer look at the number of employees within an organization, we see that knowledge about BIM is better in bigger organizations (>1000 employees)

Conclusion: knowledge about BIM is better in bigger organizations (>1000 employees)

Recommendation:

- If we want BIM as a new standard for building our roads, we need to educate and accompany all National Road Authorities in implementing the BIM method.
- A broad communication campaign can be done to proclaim why BIM is the most inclusive method to build and maintain roads.
- If we drive on BIM in the road sector, we should request universities and high schools to focus more on BIM. Because younger generation has more digital literacy than older generation.

3.3.4. Results of the survey. “Using BIM in a pilot project.”

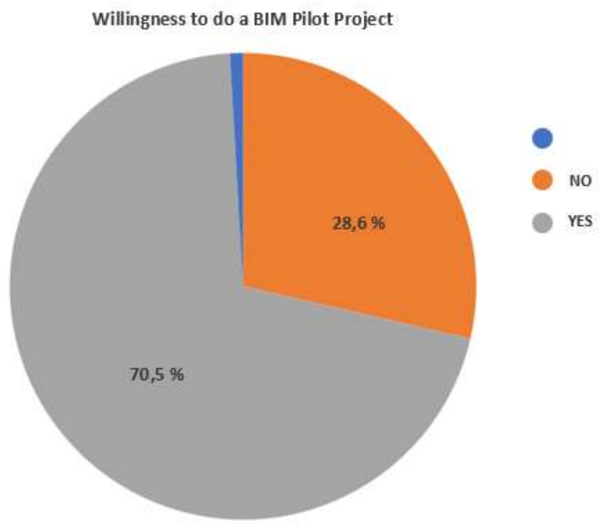

Illustration 24. Survey results “Using BiM in Pilot Project”

About 71% of the respondents wants to do a pilot project with BIM.

3.3.5. Results of the survey. “Are you currently working with BIM?”

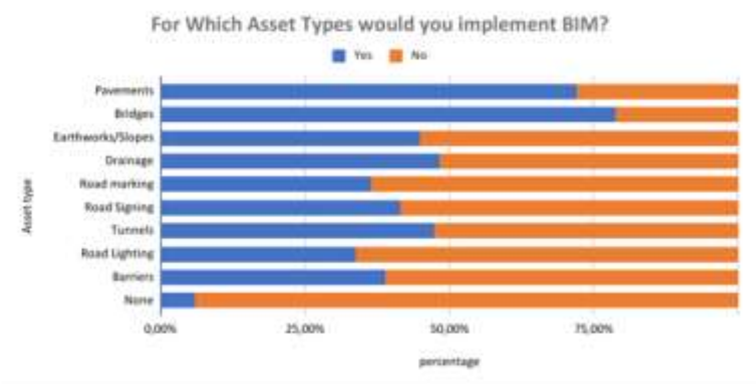

Illustration 25. Survey results” Asset types in BIM”

A road agency has various assets to maintain. On the question “For which type of assets would you implement BIM”, the respondents indicate that BIM for Drainage, Tunnels, Earthworks/slopes and roadsigning is less preferable to implement then BIM for Bridges and Pavements. Also, Barriers, Road Marking and Road Lighting are less favourable assets for the implementation of BIM.

Conclusion: BIM will mainly be implemented for 'hard' materials like bridges and pavements, while it's less favourable for 'soft(er)' like roadmarking, road lighting.

3.3.6. Results of the survey. "Asset types for which BIM is already envolved"

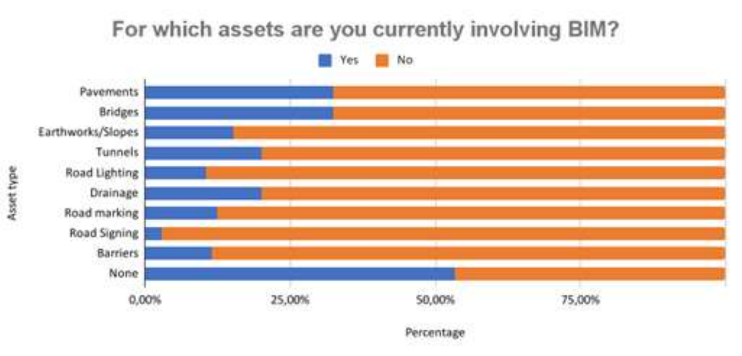

Illustration 26. Survey results "Asset currently involving BIM"

We see that most of the respondents don't use BIM at all now.

If it's used, pavements and bridges are the most popular assets. BIM is also used for Tunnels & drainage by the respondents. Earthworks/slopes, Road Marking, Barriers, Road Lighting, Road's signing are assets, in which BIM is less involved.

Conclusion: BIM is mainly be implemented for 'hard' materials like bridges and pavements, while it's less favourable for 'soft(er)' like road marking, road lighting.

3.3.7. Results of the survey: "In which phase of the process is it relevant to use BIM?"

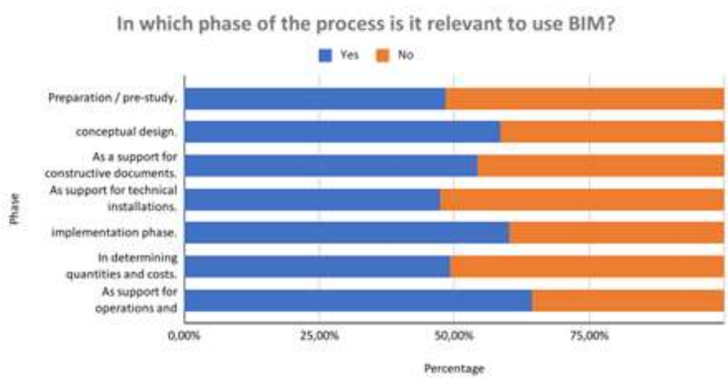

Illustration 27. Survey results" Phase process relevant BIM"

We see that BIM seems to be relevant during the most important phases of a project. So, it would be relevant in the conceptual design, during the implementation phase and most relevant as support for operations and maintenance.

The question is not only asking for a phase in which BIM is relevant, but also asks about BIM modelling applications.

3.3.8. Results of the survey: “What are your reasons for not working with BIM?”

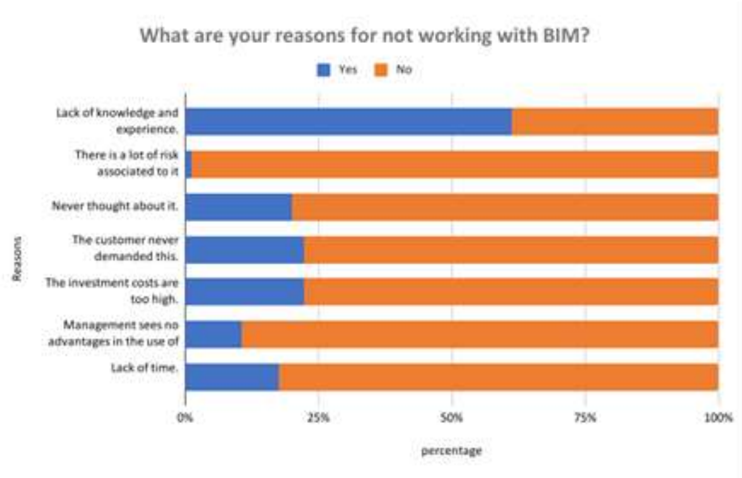

Illustration 28. Survey results “Reasons not working with BIM”

Around 75% of the respondents are currently NOT working with BIM (see 1). The main reason for not working with BIM can be found in a lack of knowledge and experience. The other reasons (see graph below) are minor, though not less important.

Conclusion: BIM is an expertise, which requires a lot of knowledge and experience

Recommendation: It would be useful to inform more about WHY BIM could be an advantage for an organization and guide the organizations who start with their first BIM project(s).

3.3.9. Results of the survey: Would you like to incorporate BIMin the future as part of the asset management process?

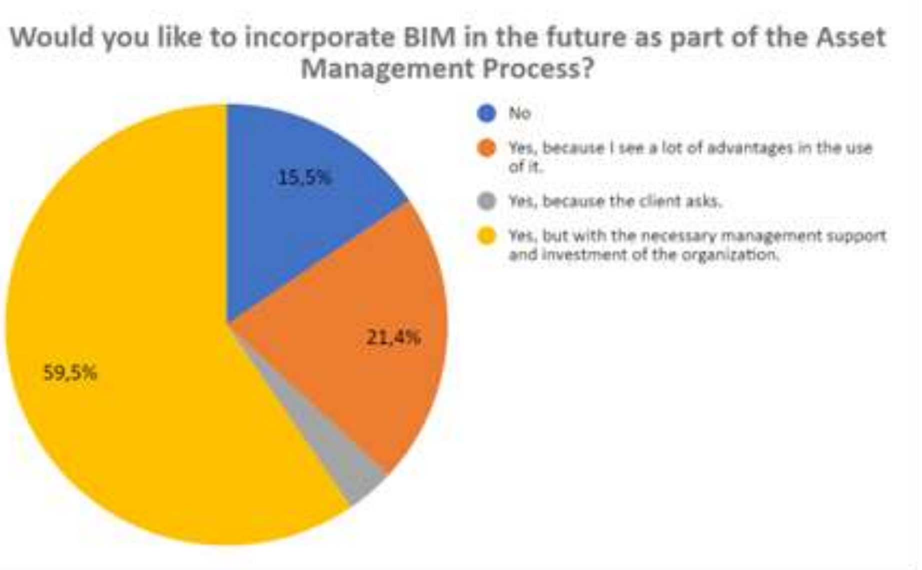

Illustration 29. Survey results “Incorporation of BIM in Asset Management Process”

Only about 15,5% of all respondents would not like to incorporate BIM as part of their Asset Management Process. The other respondents are in one way, or another interested in using BIM as part of their Asset Management Process.

Small organizations (<100 employees) answered more "No" to this question, than bigger organizations, but those who answered "No" do not come from a specific sector. In other words, larger organizations have high motivation using BIM maybe because they expect BIM is useful to manage a large scale of road assets.

Conclusion: It is thought that BIM is useful for asset management supporting method.

Conclusion: We see that Management support is a very important precondition

Conclusion: Smaller organizations are less willing to incorporate BIM as part of their AIM

3.3.10. Case: BIM in Spain

Given the need for Spanish companies to approach new construction processes and international tenders related to new technologies, the BuildingSMART Spanish Chapter was created in 2012 as a private non-profit association, grouping companies in the construction industry that want to promote the BIM development in Spain. This chapter of BuildingSMART and the Association AENOR collaborate to draw up the ISO regulations to manage and develop new technologies.

BuildingSMART Spanish Chapter continually works on promoting standards for open formats or also known as OpenBIM, in addition to creating BiM as the first standard guide in Spanish for the use of these technologies. The first 13 documents found in it are a translation and adaptation of the guide prepared by the Finnish chapter of BuildingSMART and more than 80 independent professionals participated in its writing. It currently consists of 14 documents that facilitate the creation of BIM content and can be found through its website. (UBIM Guides, 2020).

Illustration 30. BuildingSMART Spanish Chapter User Guide

Spain, like other countries of the European Union, have followed the Directives of the European Union to support BIM policies, promoting the creation of programs throughout the continent. In 2015, the BIM Commission was created, made up of agents from the public and private sectors to define implementation strategies at the national level, strengthen the application of BIM in the public sector and promote interoperability between tools for free access to technology.

The commission is BIM created an observatory in order to verify the progression of the requirements contained in public bidding documents and analyse how the following BIM points influence bidding documents:

- BIM uses considered.
- Levels of detail
- Deliverables
- Use of open formats
- Collaboration requirements

The seventh report of the commission's observatory collects 517 public tenders that include some BIM requirements and have been published from the beginning of 2017 to the first half of 2019. The following map shows the distribution of projects that are the object of the contract of the tender made by each autonomous community. (Palermo, Campos, & Pérez, 2019)

Illustration 31. Map of the distribution of the estimated value of the total contract accumulated by CCAA

3.3.11. Case: BIM in Belgium

In the past few years, the development of BIM has progressed strongly, due to its increasing use in the sector. As a result, the challenges associated with its implementation are also becoming broader as well. This implementation is not obvious to everyone, and each company deals with it in its own way. In order to create a better picture of what these challenges are and what limitations are experienced today in the (road) construction companies in Belgium, a survey was carried out. The survey was based on an impact analysis, consisting of 4 different phases: the demographic background of the respondents, the BIM maturity of the respondents, the benefits and drawbacks of BIM and the respondents' vision of the future.

The questionnaire showed that 55% of the respondents are broadly familiar with the BIM process and 32% have a broad knowledge of the BIM method. However, there are still a small number of people in the sample who have never heard anything about the BIM concept. When focusing on this group of respondents, it appears that most of them are active in the road construction sector. In addition, 57% of the respondents have been able to make the transition from a traditional building process to a building process with BIM and have already worked with BIM. It is striking, when looking at the company profiles of these respondents, that most of those who have been able to make this switch are present in civil engineering and that in the group of respondents who have never worked with BIM, the road construction sector is at the top with 47%. It is essential that this group, who are turning their backs on BIM, receive the necessary attention because they constitute one of the barriers that make the implementation happen gradually. The main reasons for this reluctance in this research are the lack of knowledge and experience, insufficient demand for BIM by the customer and the lack of time to realise the switchover. This is in line with the research of the University of Twente, where the lack of knowledge and experience was also at the top of the list of barriers blocking the implementation of BIM. Furthermore, the implementation of BIM in the (road) construction sector is receiving a great deal of attention today because it goes hand in hand with various advantages. The main benefit experienced in the use of BIM in this study is first and foremost increased productivity, followed by an increase in project staff involvement/increased cooperation and less unforeseen costs. This is consistent with Salman Azhar's (2011) research which showed that the integration of BIM primarily improves communication and cooperation between the various project partners, that in turn leads to an increase in the efficiency, productivity and quality of the product and a reduction in failure costs. Moreover, the research carried out by the University of Twente is also in line with this, which showed that the most important drivers of BIM are working more efficiently and reducing failure costs. Reducing failure costs can be achieved by the presence of a clash detection, where the errors are already filtered at an earlier stage. For these reasons, the clash detection is one of the most important applications of BIM in this study, which is in line with several similar studies.

In order to further analyse the results and to be able to generalise them to the population, correlations were drawn up and t-tests were carried out in order to compare the averages of two different groups. When assessing whether there is a relationship between the sector and the degree of digitisation, a significant correlation is found, which is interpreted as follows: the sector has a moderate positive correlation with digitisation, with civil engineering making more use of digitisation than road construction.

It can be concluded that most companies have already made the switch to a digital company or are in the process of preparing to do it in the near future. It is remarkable in this respect that, unlike the other sectors, the road construction sector has experienced a certain delay. In addition, there is also a difference between the degree of digitisation of large and small companies. The small companies, who are less digitised, hinder the further evolution of BIM. They are less able to make the switch due to a lack of money and resources but are obliged to go along with the rest because it is almost impossible to do otherwise. However, the fact that many small companies have yet to make the switch means that the further evolution of BIM is hampered, as the BIM process only works if all links, including small subcontractors, cooperate. One of the limitations of this investigation was the period in which it took place. The appearance of the COVID-19 virus caused most companies to have their staff working from home, resulting in most potential respondents not having time to complete a survey. The survey was finally completed by 122 participants, which is still a low number. In addition, it is undeniable that there have been a considerable number of surveys on this subject lately, which has led to a decline in interest in completing the survey. Finally, the second part of the survey, which gives a broader picture of the respondents' point of view, was only completed by 34% of the participants and compared to the first part these respondents had a more positive view on the BIM story. This was then considered when interpreting the results. (Uzunbacak, Blommaert, Van den bergh, & Vuye, 2020)

3.3.12. Case: BIM in Mexico

In Mexico, the use of BIM is not compulsory, however the public sector has used the methodology in some isolated cases, like the Mexico City New International Airport (NAICM), some public hospitals, and for the maintenance and operation of a research plant for the National Service of Health, Safety and Agri-food Quality. On the other hand, there are cases in the private sector that have decided to use the BIM methodology by themselves on governmental projects. In 2017, it was published the first Mexican norm focused on BIM: NMX-C-527-1-ONNCCE-2017.

In March 2019, the Ministry of Finance made public the “Strategy to implement BIM in Mexico”.

The aim of this strategy is to deliver infrastructure projects on time and in compliance with the corresponding specifications.

The strategy is set forth from a government perspective to support its materialization. The strategy will be implemented in phases to allow sufficient time to develop skills, capabilities, and processes so that the maximum potential of the methodology can be achieved, considering an 8-year time span.

From 2018 to 2021 it was considered to prepare, adapt, and implement the strategy to use BIM for Investment Projects and Programs, Public-Private Partnerships, and some concessions schemes that meet the following selection criteria:

Table 1. Strategy to use BIM

Type of project	Quantitative criteria	Qualitative criteria
Investment Projects and Programs	≥ 1,000 million pesos (~ 50 million USD)	New economic and social infrastructure
Public-Private Partnerships	Not defined	Infrastructure projects

Concession schemes	Not defined	All Construction and modernization projects

Specific objectives of the strategy:

- Foster the use of the BIM methodology for infrastructure projects.
- Improve processes of public infrastructure projects by using the BIM methodology and technologic tools.
- Promote the participation of the private sector and other agencies in the strategy to complete the value chain.
- Use the results of the methodology for continuous improvement in the infrastructure.

The development of strategic objectives is supported by three key elements. Public policy, processes, and culture, in addition to the latter, are complemented by a transversal element, technology.

Strategy implementation road map

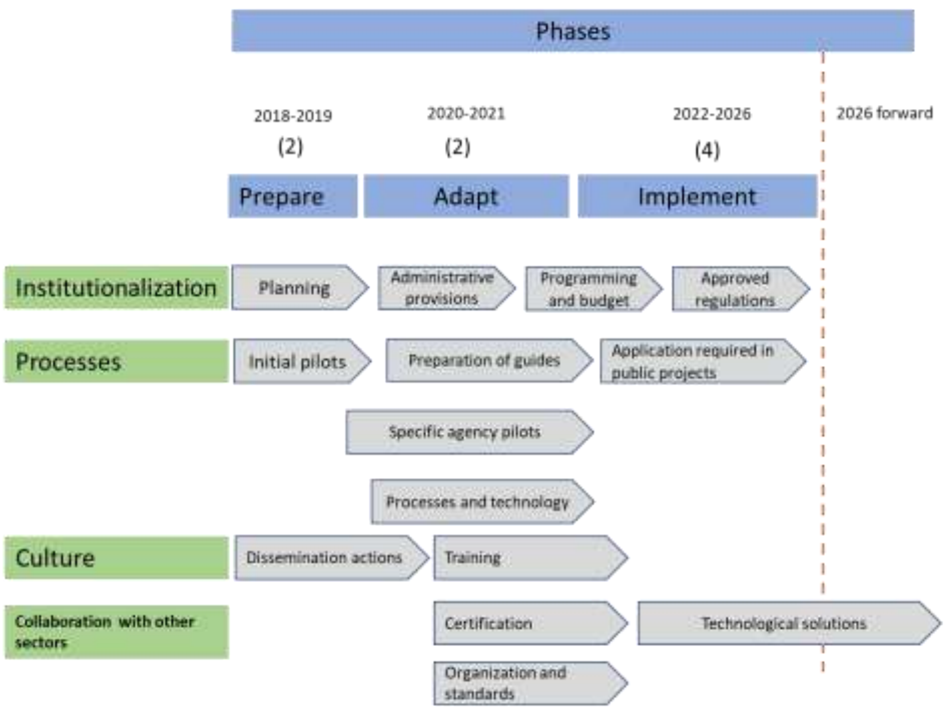

Illustration 32. Strategy map

The Ministry of Communications and Transportation Infrastructure through the Road Department (road design and construction, Dirección General de Carreteras) has followed the strategy road map by developing initial pilots for some federal road investment projects. There is still a lot of ground to cover based on the BIM Strategy, in road asset management for the federal road network and existing toll road concessions and PPPs.

3.3.13. Case: BIM in France

The choice made by France is not to make BIM mandatory, but rather to encourage its use. According to a study conducted by Majors Consultants in January 2022, 48% of industry players are convinced that BIM is a strategic issue for their business (+11 points compared to the previous edition of the barometer). 66% of those who work in BIM are convinced of its usefulness and importance (+10 points) and 17% have deployed actions in favour of BIM in their company.

The digital transition must be as inclusive as possible. BIM must be made available to for all professionals, especially for the many particularly for the many SMEs and craft and artisanal companies in the sector, and to be established in all the territories. To make the digital transformation of the building industry a reality, the public authorities have set up a funded program called "plan BIM 2022". This program includes two priorities:

- to generalize the procurement in BIM in the whole the entire construction sector by accompanying and securing it.
- to provide the players with the necessary tools to work in BIM through training, the provision of suitable collaborative tools and the dissemination of these tools in the territories.

Building SMART is the worldwide industry body driving the digital transformation of the built asset industry. buildingSMART is committed to delivering improvement by the creation and adoption of open, international standards and solutions for infrastructure and buildings. buildingSMART is the community for visionaries working to transform the design, construction, operation, and maintenance of built assets. buildingSMART is an open, neutral, and international not-for-profit organization.

French chapter, buildSMART France – Mediaconstruct, gathered the actors of the French sector, mostly oriented in the building area. Launched in 2014, the National Research Project MINnD (Modelling Interoperable Information for Sustainable Infrastructure) worked on structuring the information used to model infrastructure in its design, construction, and operation phases.

Recognized as a structuring project, guaranteeing a shared public/private vision at both national and international levels.

Production of numerous deliverables now available on minnd.fr/liveable (French and English)

MINnD (2014-2018) has met its initial objectives, that of increasing the skills of the entire French construction sector in terms of BIM practice for infrastructure

The research is still relevant, and the expectations of the project partners remain high. The work is therefore being pursued within the framework of a new project, "MINnD Season 2" (2019-2022). This program is structured around 6 themes of research and reflection:

- The structuring of the data
- The qualification of the data.
- Digital continuity
- BIM-GIS convergence.
- Asset management
- Collaboration.

3.3.14. Case: BIM in Japan

To the Japanese government initiatives (such as the promotion of digital transformation (DX) and digital innovation, the strengthening of growth strategy, the streamline of the infrastructure improvement toward the next generation, the improvement of the productivity of infrastructure development and so on), and also from the strong and broader demands of infrastructure industrial society, BIM activity has been promoted and coordinated under the Committee of BIM Promotion Committee, Ministry of Land, Infrastructure and Transport (MLIT) since 2019.

The BIM Promotion Committee has formulated a road map for implementing BIM as follows. It describes that BIM will apply to all infrastructure projects by FY2025 in principle. And the roadmap focuses on 3 purposes in order to promote BIM application:

1)Standardization, MLIT will proceed with standardization of attribution data, that conform to 3D data standards "IFC5" in fiscal 2021, and target at standardization of 4D (3D+ times-axis), 5D (4D+ cost-axis) in fiscal 2025.

At the first stage of BIM introduction, BIM will be applied at the large-scale structural designs, and construction will be implemented with the results of 3D BIM prepared in the design process.

2)Dissemination/Facilitation, MLIT will develop and promote BIM environment for the improvement of productivity and user-friendly system. This includes human resource development and training for suing BIM for consulting firms (survey and design), universities, construction companies, mechanical companies (survey equipment, monitoring equipment, construction machineries and others). The wide range of coordination is needed among government sector, industrial sector, and academic sector.

3)Advanced Utilization, it will aim to realize business reforms premised on utilizing BIM to streamline and upgrade public works and promote continuous business improvement. At the BIM first implementation stage, it mainly focused on the construction phase because BIM users can feel the usefulness and the productivity.

Therefore, at this moment, any case studies for asset management using BIM are not materialized in Japan. However, the case study will be hoped to be formulated near future because Japanese infrastructure is in the aging stage.

Road Map for BIM in Japan

(The BIM Initiative, Ministry of Land, Infrastructure and Transport, in Japan)

BIM Promotion Committee, Ministry of Land, Infrastructure and Transport, Japan

- BIM will apply to all infrastructure projects in principle by FY 2025.
- In order to promote BIM, the purpose of BIM is categorized into 3 targets, 1) Standardization, 2) Dissemination & Facilitation, 3) Advanced Utilization.

Purpose	Overview	Items	Target for FY2021	Targets for FY2025
Standardization of criteria on BIM	BIM utilization can implement the seamless operation of information so that all persons involved in construction/production/management systems	Standardization of shape and attribute information	Standardization of properties in conformity with IFC5	Standardization of 4D/5D
		Standardizing workflows	Authorization of standard requirements for deliverable outputs	Improvement of business efficiency by standardizing workflow
		Standardization of domestic standards	Standardization of domestic standards such as software functional requirements	Harmonization of Japanese Industrial Standards for BIM
Dissemination & Facilitation of BIM	Government will develop and promote BIM environment for the improvement of productivity and user friendly system	Further expansion of BIM projects	Establishment of BIM guidelines for infrastructure common fields	BIM application to all infrastructure projects in principle (regardless of field)
		Human resource development of BIM engineers	Establishment of dissemination systems	Sophistication through data management utilizing engineers
		Dissemination of tools that contribute to improved efficiency	Implementation of modeling support tools such as parametric models	Implementation of partial automatic drawing and design checking by mechanical processing
Promotion of advanced utilization of BIM	Government will aim to realize business reforms premised on utilizing BIM in order to streamline and upgrade public works, and promote continuous business improvement	Quality assurance and improvement of public works	Realization of quality assurance of products through 3D designing audit	Establishment of supervision and inspection procedures for survey, design, project quality control and inspection related BIM
		Comprehensive review of BIM workflow	Standardization of BIM contracts mainly for survey and design	Standardization of BIM contracts for whole project phases
		Expanding the use of data	Facilitation of secondary use of BIM modeling (public involvement, etc.)	Facilitation of 3D data in data platform

Illustration 33. Road map for BIM Japan

The following paragraphs explain "BIM (Before and After)" and "BIM (Without and with)" in order to imagine the advantages of BIM using materials made by MILT.

As show in the figure BIM (Before and After), the following advantages can be realized by introducing BIM:

- Planning
  - Explanation using 3D model (improvement of understanding)
  - Assistance of implementation plan (time wise) by stages
- Survey/Design / Procurement
  - Check of interference of steel bar by 3D on design documents
  - Automation of BOQ calculation using 3D
  - Work will be more integrated (drawing, cost and time)
- Construction/Supervision
  - Design changes can be made on 3D (time and cost saving of design change by automatic of VOQ calculation.)
  - Final inspection can be made by point cloud data (i.e. check within margin error or not). Cost and time saving can be possible in inspection work (earth work, pavement, etc.)
  - Monitor of construction process remotely using wearable cameras, etc. (reduce travel time, improve efficiency of inspection process, facilitate construction processes, improve safety)

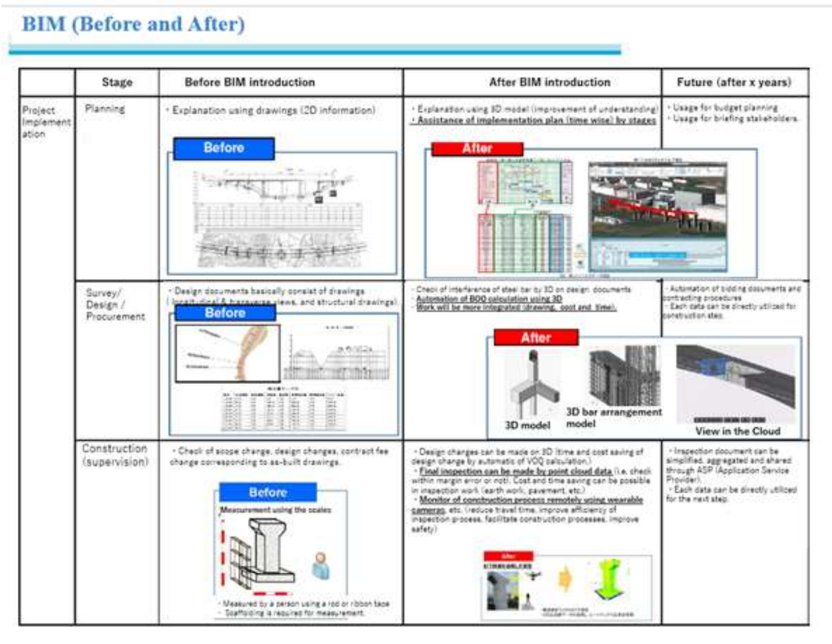

Illustration 34. Before and After BIM

The following figures show the advantages of maintenance stage and disaster management using BIM. This has not implemented now.

- Maintenance
  - Maintenance plan is made by digital data such as data base linked with GIS, image data.
  - Inspection data collected by sensors. It can be visualized by 3D.
  - Maintenance plan will be used deterioration model and AI.
- Disaster Management
  - It can save time to compare between before-after disaster sites of point cloud data by LS (Laser Scan) survey.
  - LS survey is carried out by multi-beam scanner suing UAV, MMS (mobile mapping system).
  - Information linked with sensors and AI forecast can be provided.
  - improve safety)

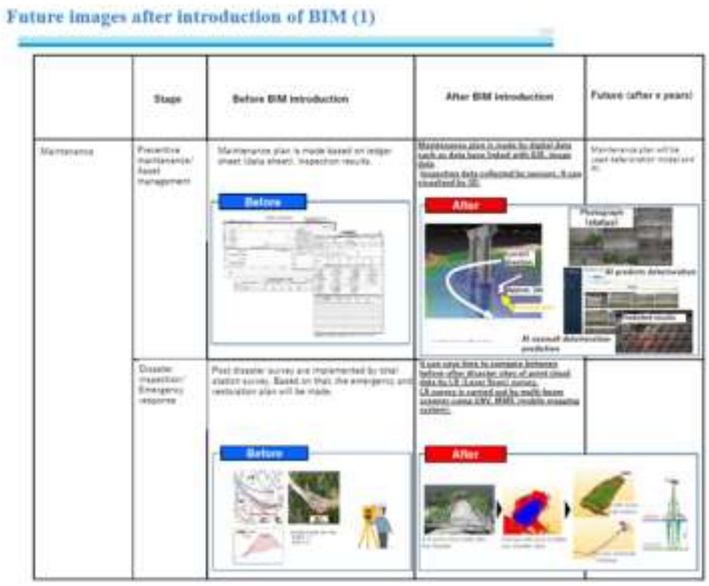

Illustration 35. Future image after introduction on BIM 1

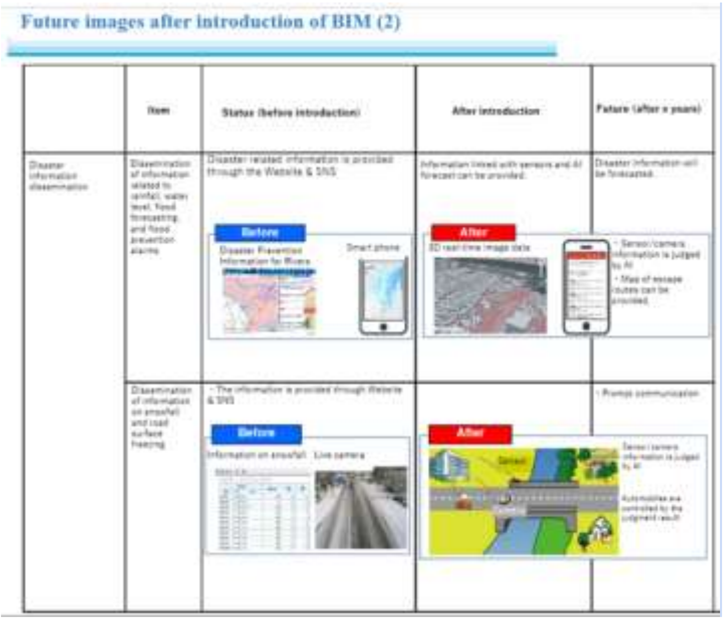

Illustration 36. Future image after introduction on BIM 2

3.3.15. Case: BIM in Korea

In 2018, Korea published 'Smart Construction Roadmap 1.0' (2018) to activate smart construction technology during the life cycle stage of the construction industry. It is proposed to introduce 3D printing, Off-Site Construction, Machine Control/Machine Guide, etc. based on BIM. Since then, in Korea, to spread the introduction of BIM at the public sector, first, BIM-related policies and a detailed strategy is presented to disseminate BIM in stages. In order to achieve this detailed strategy, the Ministry of Land, Infrastructure and Transport has expanded the BIM application test bed of the turnkey projects from 2019, prepared 'Basic Guideline' as BIM-related national guidelines, established the national BIM Centre, which plays the role of a control tower. Many strategies are being prepared in all directions, such as promoting BIM S/W activation and expanding standard educational functions. In December 2020, as the highest-level guideline for national BIM, the 'Basic Guidelines for BIM in the Construction Industry' were published, defining the BIM definition, scope, common procedures for BIM application, standards, and principles and standards for establishing a collaborative system. Afterwards, the 'BIM Implementation Guidelines' containing detailed common implementation plans of the basic guidelines were published. Each owner (public ordering organization) plans to prepare 'BIM application guidelines' by the second half of 2022 for each field (road, railway, port, construction, etc.) based on this implementation guideline. Through the recent preparation of 'Smart Construction Activation Measures', digital transformation of the entire construction industry is promoted through the introduction of BIM in the mid- to long-term.

As for BIM in the domestic road sector, the Korea Expressway Corporation pre-emptively mandated the introduction of BIM. In accordance with the government's policy direction, the entire BIM design has been applied step by step from the design stage. Recently, all new highway construction projects have made it compulsory to design the Full BIM. Korea Expressway Corporation has already analysed the technical feasibility of introducing BIM through BIM design through a few BIM pilot projects since 2011. After that, it published its own 'Ex-BIM Guideline' and started placing orders for BIM projects for some unit projects, and through the preparation of 'Smart Design Guidelines', a full BIM-based design is performed for the design of new highways. In the railway sector, with the Osong-railway test line BIM pilot project, BIM is being applied to the Daejeon North connecting line and Wolgot-Pangyo double-track train project, and its own BIM application guidelines have been prepared. In addition, Land & Housing Corporation and Korea Water Resources Corporation promote the application of BIM to the various areas. In the field of architecture, BIM is applied in stages to public buildings, and in 2017, it was already mandatory to submit BIM drawings and reports at the time of bidding.

The domestic BIM market is very small compared to overseas, but its application level is very active. Already, BIM orders in the public domain are continuously expanding, and through this, digital transformation of the construction industry is being promoted centring on BIM.

In the future, in Korea, the BIM standard system will be prepared to comply with international standards such as ISO19650 to match the digital transformation of the construction industry. In addition, it is planning to develop a digital collaboration platform to enable online BIM design and construction management by breaking away from the site-oriented BIM design system. It will enable Korea to lead the BIM market by preparing such a national strategy, establishing an action plan, and investing in technology development (R&D).

3.4. DIGITALIZATION IN THE WORLD

In this section, different surveys and their respective results are presented to show the importance of digitisation in the context of asset management, along with a series of conclusions and recommendations for each of them.

3.4.1. Results of the survey: "To what extent are you working on digitalization to support the asset management process?"

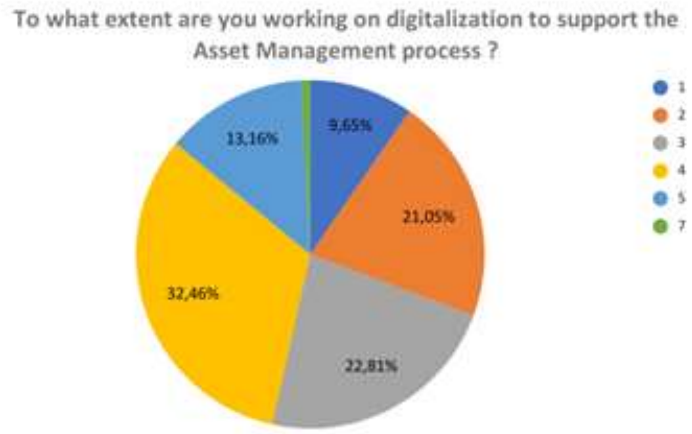

Illustration 37. Survey Results "digitalization to support asset management process"

1 = low level of digitalisation. 7=fully digitalised.

Most countries are nowadays working on digitalisation to support the Asset Management process. Most organizations (32%) rate themselves 4 out of 7. Only one Norwegian respondent rates his/her organization a 7 out of 7. Almost 54% of the respondents give themself a score between 1 and 3 out of 7. There are no significant differences between bigger or smaller organizations and between public and private organizations.

Conclusion: More than 50% of the companies are insecure about the extent they are working on digitalisation to support the Asset Management Process.

3.4.2. Results of the survey: asset(s) you collect or maintain data on

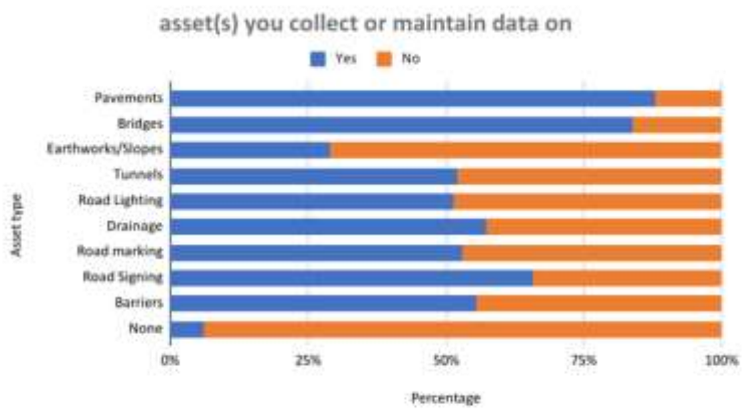

Illustration 38. Survey results "collection data"

Most organizations maintain data on their most important assets such as pavements and bridges. Also, Road signing is an important data source. Earthworks/slopes are one of assets where the fewest data is collected about.

Conclusion: Most data is collected about pavements in bridges

3.4.3. Results of the survey “do you collect data on inventory with your own staff or do you require contractors/consultants to deliver you data on inventory?”

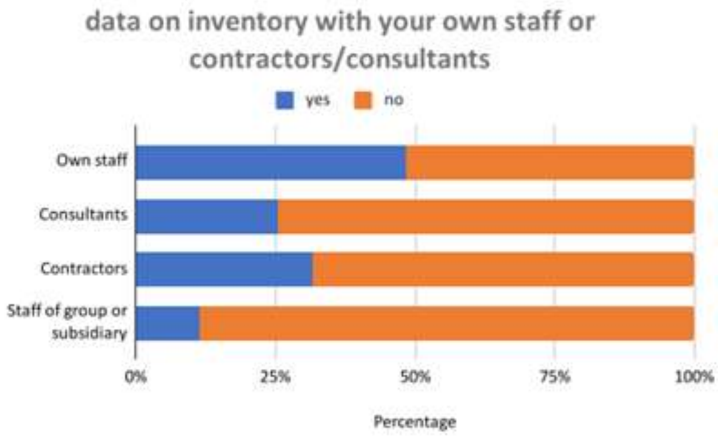

Illustration 39. Survey results “collect data on inventory”

Most organizations collect data on inventory with their own staff, but it’s not a vast majority. Most organizations hire external workforces (most of the time in addition to their own staff) to get their inventory up to date.

We see that African organizations and North American organizations are working more with their own staff then organizations of other continents.

We also see that public sector organizations are less likely to collect data with their own staff.

Conclusion: Digitalisation is a difficult matter, which requires special trained workforces besides the own staff.

When an organization drives to digitalisation on asset data, it may be preferable to engage in-house staff because of special skills for using equipment of data collection (digitalisation).

3.4.4. Results of the survey “Data collection according to type of asset”

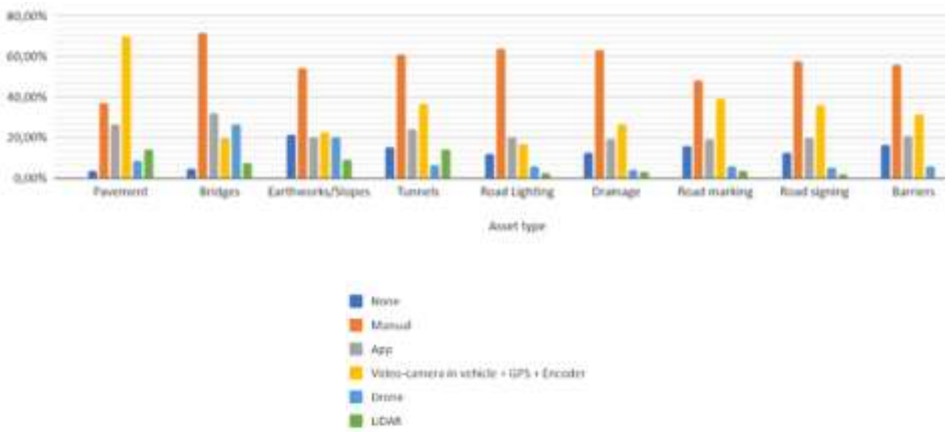

Illustration 1. Survey results “data collection according to type of asset”

Data can be collected in different ways and for different types of assets. Therefore, we look per asset type which data collection methods are used.

Conclusions: LiDAR and Drones are not common for data collection methods now

Conclusion: Most data collection is done manually

Conclusion: Only for pavements a in vehicle camera + GPS + Encoder is used intensively.

Recommendation: It would be useful to inform more about the different data collection methods and provide some educational material to get started.

The level of digitalisation is mainly GIS related. We see that the level of digitalisation of pavement and bridges are much higher than the rest of the asset types.

On the other hand, we can see that BIM related digitalisation is almost for each asset type below 5%, only for pavements and tunnels it goes above the 9%.

Conclusion: Besides pavements and bridges, the overall level of digitalisation is "medium"-" low".

Recommendation: It would be useful to inform more about why BIM could be an advantage for an organization and guide the organizations who start with their first BIM project(s).

3.4.5. Results of survey "level of efficiency of sharing the data to other units / departments within the organization"

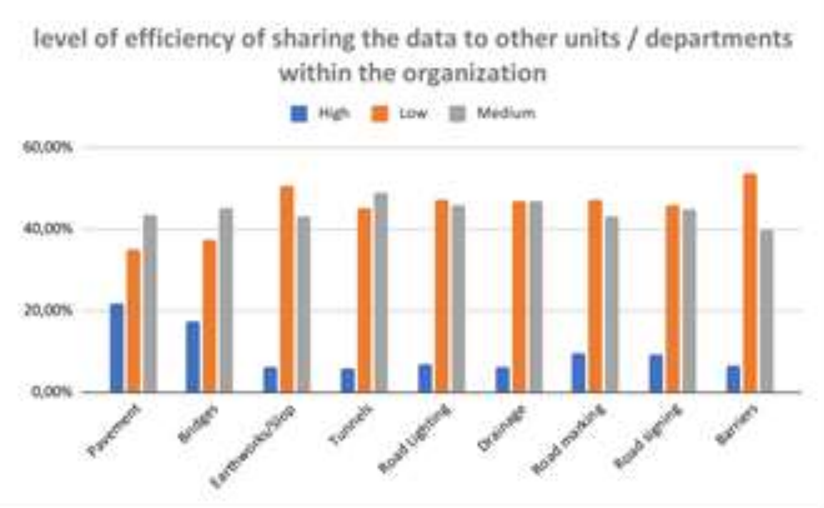

Illustration 40. Survey results "efficiency of sharing data"

This graph indicates the level of efficiency of sharing the data to other units / departments within the organization. We see the overall trend is rather "low" - "medium", but not "high".

Conclusion: Data is mainly collected in Silos, which takes a lot of effort to (re)use the data within the organization.

3.4.6. Results of the survey “asset condition”

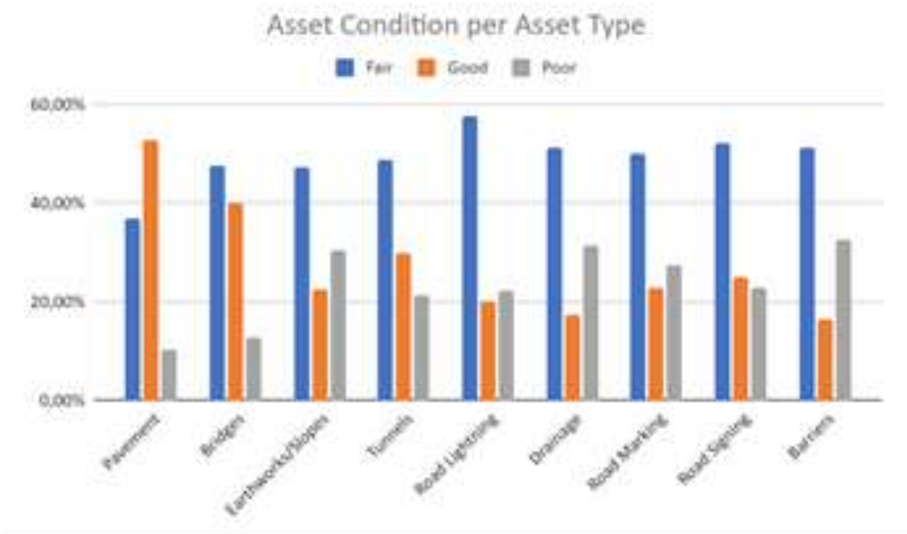

Illustration 41. Survey results “asset condition”

For Pavements, the overall trend is “Good”. While for the other asset types of the respondents perceived the asset condition as “fair”. We also see that for Earthworks/slopes, Road Lightning, Drainage, Road Marking and Barriers the asset condition is perceived more “Poor” than it is perceived as “Good”

Conclusion: The overall asset condition can be improved

3.4.7. Results of the survey “inspection frequency”

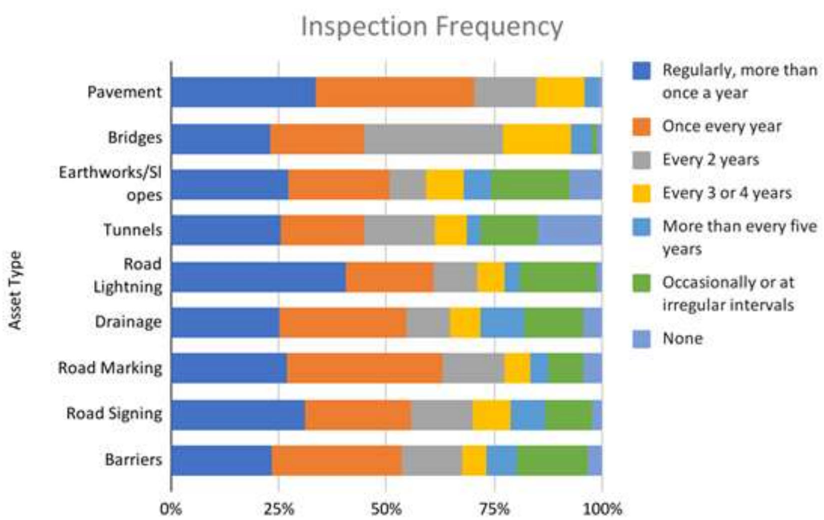

Illustration 42. Survey results “inspection frequency”

In 50% of the cases the assets are inspected at least once a year. Only tunnels and bridges are less frequently inspected.

Remark about the results: Surprisingly, a large share of tunnels are never inspected. The reason could be that there are no tunnels in the respondent’s jurisdiction

3.4.8. Recommendation: A higher inspection frequency could possibly improve the asset condition

3.4.9. Results of the survey “inspection equipment”

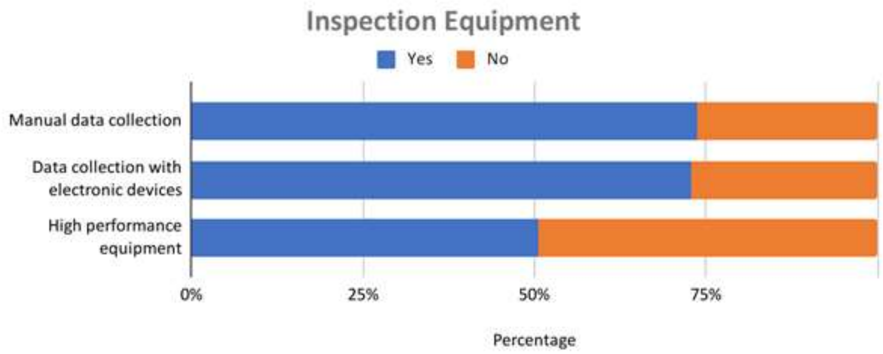

Illustration 2. Survey results “inspection equipment”

When assets are inspected, they are mostly inspected manually, mostly in combination with electronic devices. About half of the inspections are done with high performance equipment

Conclusion: The overall inspection equipment could be improved.

Recommendation: A better inspection equipment could possibly improve the asset condition.

Recommendation: A better inspection equipment could lower the inspection time, which could improve the inspection frequency, because inspectors have more time.

3.4.10. Results of the survey “assets using sensors”

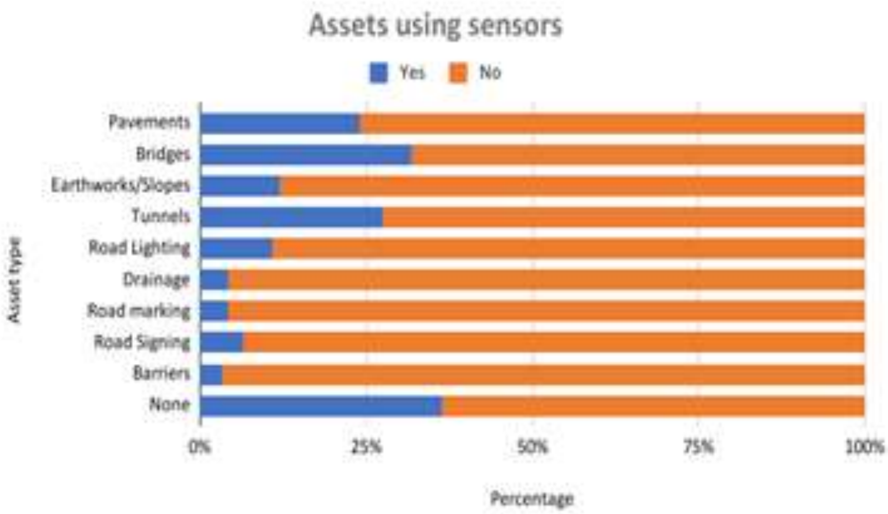

Illustration 43. Survey results “assets using sensors”

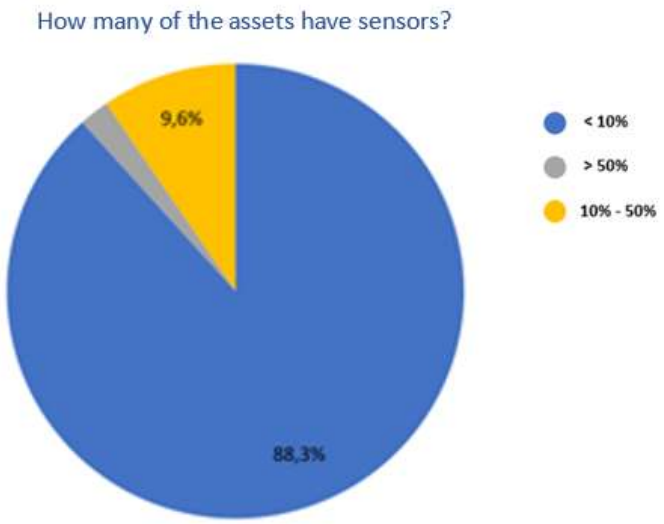

Illustration 44. Survey results "how many assets have sensors"

Almost 90% of the respondent's state that less than 10% of their assets have sensors. If they have sensors, they are mainly used in bridges, tunnels, and pavements.

Conclusion: Tunnels and Bridges are the less inspected assets (see above). But they are more likely to have sensors on it, which could mean that these assets are digitally monitored and therefore don't need as many inspections as other assets.

3.4.11. Results of the survey "how does the communication and cooperation between the different project partners take place?"

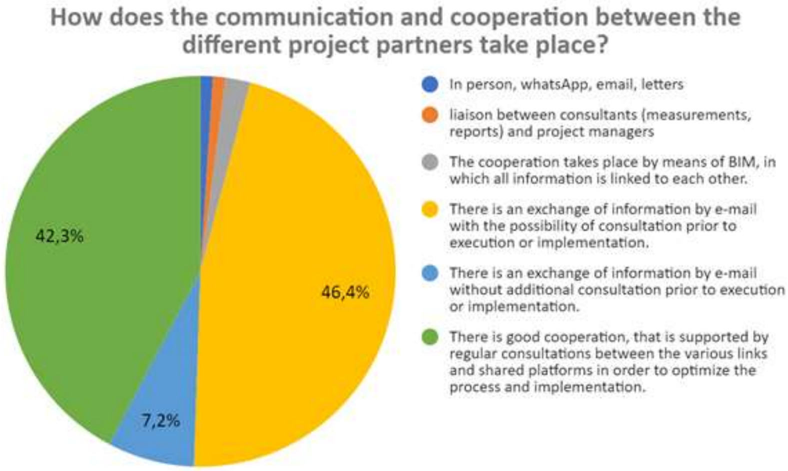

Illustration 45. Survey results "communication and cooperation"

More than half of the respondents stated that they mainly communicate through email. But there are also a lot of respondents that state that there is good cooperation that is supported by regular consultations between the various links and shared platforms to optimize the process and implementation. Around 5% of all respondents, communicate through other channels.

4. STATE OF THE ART

The current status of the application of Building Information Modelling (BIM) and Digitalization in road asset management internationally will be discussed. Trends, developments and best practices in this field will be examined. This analysis will provide an understanding of the current landscape and opportunities in the integration of BIM and Digitalization in road asset management worldwide.

4.1. BIM SOFTWARE

When actually modelling the model, all the relevant BIM-data needs to be shared in a Common Data Environment (CDE). An example of such a platform is BIM360. But other software is available. On such a platform BIM-data is gathered, managed, and scattered to all parties. This makes it possible to co-work through one single platform. But it is also possible to share data from other projects that is relevant for the current project.

Archicad is considered the first BIM software, although they did not name it this way themselves, but it is because of the creation of the first version of Archicad that the real development of platforms that allow the creation of intelligent construction models begins. In its first versions Archicad allows the user to interact between plants, elevations, and sections without the need to create separate files, all the information is extracted from a 3D model.

Autodesk presented in 2000 a platform capable of conceiving a project and all the information necessary for its creation on the same platform. It is from the creation of these software that it can be said that there is a digital construction process, encompassing all the necessary phases for the development of a project: geometry, construction systems, facilities, structures, measurements, budgets, environmental information, specifications, simulations, etc. (Choclán, Soler, & González, 2014).

The correct use of a BIM model can help not only the design and construction of infrastructures, but also their management and maintenance. The process of creating BIM models gives rise to the interaction of all the agents involved in the entire life cycle of construction and with it, different software and computer programs that help manage effective workflows, for this it is necessary to generate interoperability between the different software.

Autodesk offers its users a list of different software that allow interconnectivity between the different items of the project, addressing the need to create different phases within it. The life cycle of an asset is represented in the following Figure 2, starting from the conceptual design and needs analysis until reaching a final phase of operation, maintenance, and demolition. At the center of the Construction Life Cycle is the database to generate each of the items, Autodesk developed the BIM 360 platform.

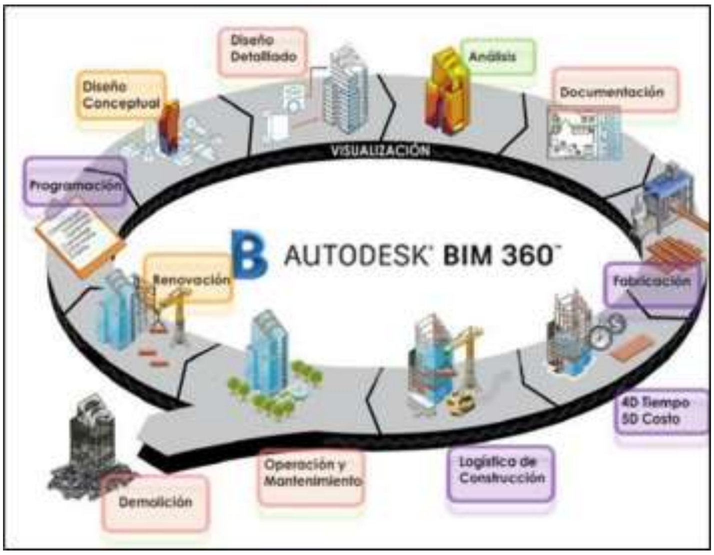

Illustration 46. Life cycle in construction

4.1.1. Data exchange formats

The Building Information Modeling concept was created from the idea of collaboration between agents, for this collaboration to be effective there must be a commonly understood and shared taxonomy with common terms, definitions, and metrics. In 2008, the "Statement of intent to support Building Information Modeling with Open Standards" was signed by the United States, Norway, Finland, and Denmark with the aim of establishing a methodology to manage the production, distribution, and quality of information in the projects of the construction, to drive and improve interoperability processes between BIM platforms. (Martin, GonzalezdeChaves, & Roldan, 2014).

In a construction project it is necessary to make efficient the exchange of plans and documents throughout the project between the client, architects, engineers, and contractors. That is why the use of BIM platforms is used, not only as a tool in the design and construction processes, but as the interface for the exchange of this between the different agents involved in the projects. It is understood that each of the agents uses different BIM software tools according to their needs, which represents a challenge for the exchange of information between different platforms and specialties.

BuildingSMART defined the term Industry Foundation Classes (IFC) as the representation of an industry standard for design models. IFC models capture the three-dimensional geometry of objects and metadata related to other aspects of the building. For example, if we consider an object in a window; the window will be located on a wall, on a floor of a building and will have associated attributes that describe its thermal performance, cost, safety performance, etc. The required attribute definitions and system descriptions are derived from legislative requirements and data entry requirements for analysis software. In recent years IFC has been used as an interoperable format, both as a mechanism for exchanging models between different software, and as a data entry format for software that has been created for design analysis and process automation.

An IFC model is defined using the ISO 10303 specifications for data modeling and exchange, also known as STEP (Standard for exchanging product data). STEP consists of a range of specifications, most notably a language for detailing data schemas, a mapping for text files, a mapping for rendering XML files applicable to models, and unique code mappings for accessing models programmatically.

Since the launch of the first version of IFC in 1996, different providers of BIM software, mainly in the architecture sector, have developed tools for the import and export of models. The tools for software dedicated to structural analysis, design of steel structures, mechanical and electrical engineering, support IFC formats, while in specialties such as environmental analysis, cost estimating, civil engineering, and facility management, not as many tools have been developed that allow the interoperability between platforms. (Steel, Drogemuller, & Toth, 2012).

The IFC language includes a wide range of modeling functions such as:

- 3D geometry
- Basic building elements (slabs, columns, beams, doors)
- Facilities management
- Electric systems
- Mechanical systems
- Structural analysis Construction

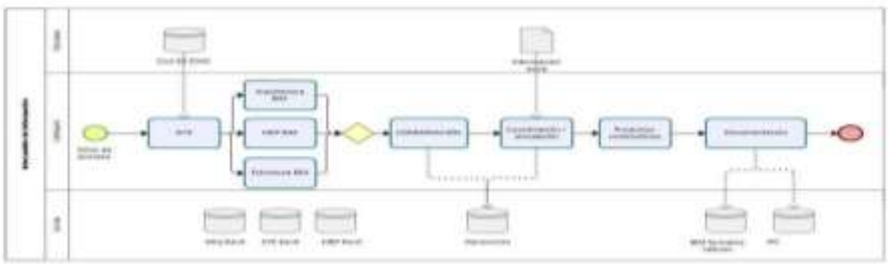

Illustration 47. Information exchange

The information is developed in native formats within the specific software of each specialty and in the event of a modification throughout the project, it is also developed in the native file to avoid collisions. The deliverable file format is IFC to facilitate the interpretation and use of the models by other agents, but not the edition of these files.

IFC files are produced as an output or STEP output format and their handling allows, unlike native language files, the use of free applications that allow viewing a 3D model, its parameters and previously assigned properties, in addition to helping collision detection by joining several models to generate a construction project.

BIM software facilitate the elaboration of a data exchange matrix that helps for the interoperability of the models. This matrix seeks to ensure that lose information during the data exchange processes, so it is important that each element contains at least the following parameters:

- Class / category / element group
- Type of element
- Element name
- GUID: unique code generated by the software.
- IFC class: ifcExportAs
- IFC type: ifcExportType
- Identifier: ifcName

4.1.2. Inspection files. GIS and BIM

In a Geographical Information System (GIS) you can store, manage, edit, analyze, integrate, and present the so-called geo-information. BIM (Building Information Modelling) is the process in which a digital representation of a building is drawn up on the basis of objects, with each its own properties. So, there are a few similarities, but the big difference is that with GIS the environment is the central component, with BIM the building is central.

If we take that into account, we can say that are complementary to each other. A structure stands in 'an environment' and without information about that environment, we cannot build a suitable structure that fits in that particular setting.

For example, GIS can provide us with the location of cables and pipes, the composition of the subsoil, existing buildings, etc. hand over. These are all important parameters to be able to erect a relevant building. In other words, GIS gives context to the BIM model of a building and enables us to map the influence of the built environment on a building as a whole.

Yet it is not unconditional love between the two worlds:

- Clear agreements must be made about data standardization. Therefore, an object type library can be used. Information about asset is standardized in this OTL. Like that everyone speaks the same language.
- The way of drawing is also important. For example, the BIM model must be drawn on coordinates, so that the information from the model can be easily linked to a location.
- But agreements are also needed about the layers in which certain object types must be drawn, so that the data can be easily extracted from the BIM model afterwards.

If these conditions are met, the foundations have been laid for a digital twin. Such a digital twin can serve as a "decision support system". In this way, numerous analyzes and simulations can be released, with the aim of improving decisions.

So, we can conclude that GIS provides the necessary context to BIM and vice versa, that BIM feeds GIS by supplying information about the new structure. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021).

4.2. Standarization in BIM

The importance of standards in the successful implementation of Building Information Modelling (BIM) in the context of road asset management will be discussed. This section will examine how to achieve good BIM standardisation, tender documents and software development.

4.2.1. Standarization in the building procces

Many companies in the Architecture, Engineering and Construction (AEC) sector have chosen the advantages of carrying out a BIM project, which represents a leap into an industry controlled by information technology (IT). One of the main qualities of BIM is the ability to create a common environment for all agents, the information and the databases that define the structural building or infrastructure.

Working with BIM advocates transparency, productivity, and quality of execution, favouring all links in the supply chain, if all the information is well documented. On the other hand, the lack of documentation of processes, mismanagement of the information obtained from a BIM model, and lack of coordination between agents are the main causes that today the potential of collaborative BIM work is not fully exploited. (Merschbrock & Munkvold, 2015).

To achieve a correct workflow, the BIM design requires different stations and a server that acts as infrastructure and support to allow communication between the different agents. The server works as a collaborative space where the BIM model is located and agents can work with it in real time, this allows having different work teams in different locations. The process is repeated in different stations with different servers, which favours the interaction of all the project's specialties simultaneously.

In the following diagram it is represented how a project can be elaborated in several cities, the information is transmitted through the network (WAN) and is sent to the field, where other agents are working on their processes simultaneously. The communication that exists between agents is permanent and the information that is distributed must always be updated. Field staff send information back to the server, which in turn is sent to the rest of the agents.

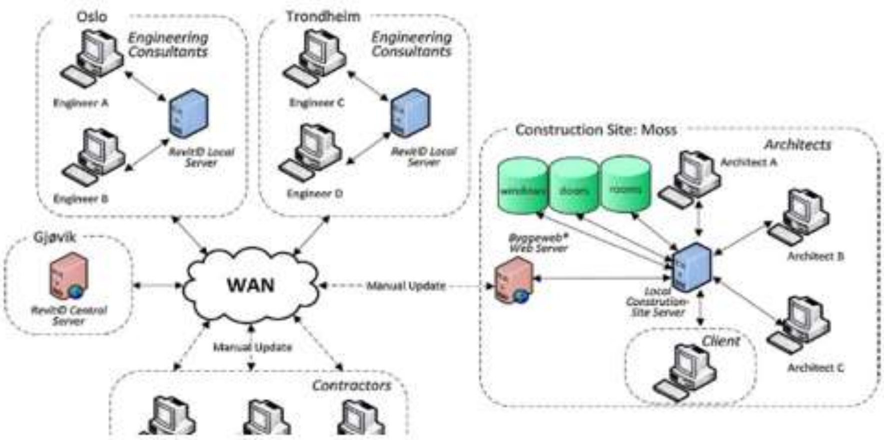

Illustration 48. BIM Server (Merschbrock & Munkvold, 2015)

The final objective of the BIM methodology is to favour the generation of information during the construction process, from design to demolition, which represents greater communication during all phases of the project. The American Institute of Architects (AIA) developed a plan to optimize the result, add greater value to the owner, reduce waste, maximize efficiency throughout the design, manufacturing, and construction phases. The plan consists of 9 sequential tasks listed below:

- Conceptualization Phase: definition of the agents who, who and how the project will be carried out.
- Design Criteria Phase: selection of design criteria, evaluation, and selection of methods.
- Detailed Design Phase: consists of making final decisions for the design project.
- Document Implementation Phase: generation and validation of documents for third parties. In this stage the technical sheets, budgets and specifications are produced.
- Agents Review Phase: the documentation of all the previous processes streamlines administrative procedures. The information of each specialty is within the model, which makes it easier to obtain permits.

- Acquisition Phase: the hiring of agents is quicker and easier; prices and suppliers are agreed from the initial phases.
- Construction Phase: the construction processes are carried out in an industrialized way, there is greater quality and time control.
- Settlement Phase: the project is an integrated model of all previous design and execution stages.
- Facilities Management: the BIM plan contemplates the exploitation and maintenance of facilities, the client makes use of the facilities, but the management and maintenance of the assets continues.

The monitoring of these 9 tasks seeks to detect errors from the design stages, increase the quality of the processes and promote communication throughout the life cycle. It is necessary to generate interoperability between processes and agents to achieve the objectives. (Choclán, Soler, & González, 2014).

4.2.2. Standardization tender documents: BIM protocol & execution plan

As already mentioned, BIM can be implemented in all project phases. The earlier BIM is used in a project, the more advantage that can be taken. To support the use of intelligent information models in all phases, to facilitate cooperation and to bring more uniformity to the BIM process, a BIM protocol and BIM implementation plan for infrastructure projects have been written.

The BIM protocol forms the basis for every BIM project. The general vision, guidelines and agreements in this BIM protocol are generally valid for all BIM assignments. Thanks to this basis, the necessary uniformity in BIM assignments is ensured. The project-specific implementation and practical agreements per project are further detailed in the accompanying BIM implementation plan that is drawn up per project. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

The BIM execution plan (PEB) is a document that describes the strategies and processes that will be applied to achieve the BIM requirements for a given project and a specific phase or phases of its life cycle. This document defines the roles and responsibilities of the agents involved in each process, defines the routes for the exchange of information and the requirements for the delivery of models and derivatives of the models.

There are several templates for the preparation of BIM Execution Plans, each one based on the regulations and needs of each country. The BIM commission prepared the Guide for the preparation of the BIM Execution Plan, and it can be used for free, the user agrees to make diligent use of the information provided, it includes a set of recommendations, in no case mandatory. The Guide was prepared to help achieve the requirements of the specifications for construction projects. (Guide for the preparation of the BIM Execution Plan, 2018).

For the development of the guide, the following were considered:

1. Recommended practices
2. Existing and non-national PEB templates
3. Minimum contents suggested in the Tender Guide
4. ISO 21500 standard related to Project Management

4.2.3. Standardization in software development

If we talk about the creation, development, and implementation of specialized Software, we must talk about a process of standardization and implementation of these new projects. BIM processes consist of the use of the software (previously defined), in real construction projects. Although the tools help us generate the 3D model, insert, or read information for each of the items, it is the different international organizations and plans that help standardize implementation parameters.

BIM adoption must take place at the appropriate scale, the agents involved must be trained to carry out their functions and projects must be oriented to the use of new technologies. The Manual for the introduction of the BIM methodology by the European public sector, designs the recommendations to work towards alignment between European countries by creating a common vision, converging requirements and a consistent terminology for digital work.

The strategic drivers for the creation of a European BIM Process Manual are:

- Creation of public projects with BIM tools.
- Promote the use of BIM for the development of public works.
- Finance the development of a common framework for the introduction of BIM projects in the European construction sector.

The continuous creation of tools has led European organizations to work together to standardize processes in the construction industry. Under this principle, manuals have been created to facilitate the use of common languages among agents, with the aim of offering Recommendations on the execution of projects and public procurement, however, these recommendations are not part of a mandate. (Bieńkowska, 2016)

4.3. BIM MATURITY LEVELS

The BewRichards BIM Maturity Model has been the most widely used representation model in the world, since it manages to graphically explain the different levels of maturity related to each type of deliverable document and the phase of the life cycle corresponding to the project. As shown in the following figure:

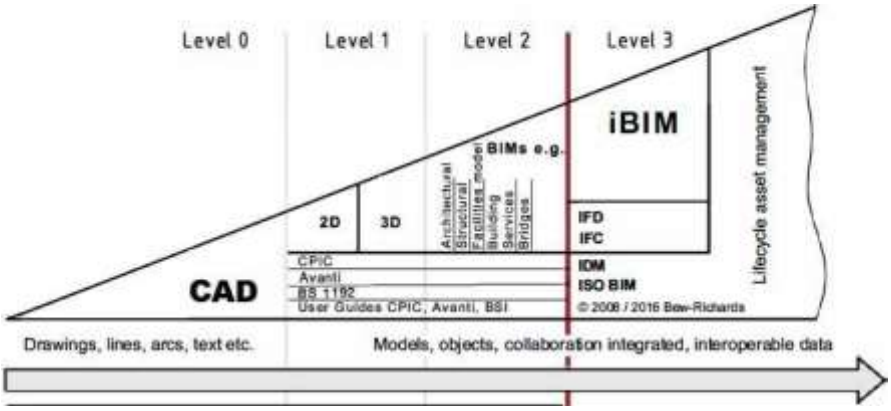

Illustration 49. BewRichards BIM Maturity Model (Rogers, Heap-Yhi, Preece, Lim, & Jayasena, 2015)

Level 0: CAD Design, working with CAD models, is a transition from paper planes to a computer-aided drawing for the representation of lines and curves on a two-dimensional plane. At this level the BIM maturity level is said to be null since there is no intelligence in it for creating layers or blocks.

Level 1: modelling, uses methodologies for the management, production, distribution, and quality of the information generated through CAD models, its representation can be in 2D or 3D and belong to a single discipline.

Level 2: Collaboration, uses processes to facilitate the collaboration and interaction of the models and the agents that use them throughout the design, construction, operation, and deconstruction, generating quality models based on objects.

Level 3: integration, integration of various disciplines using BIM models, the objective is to achieve interoperability of the models on different servers connected through a network. (Jayasena & Weddikkara, 2013).

4.4. How to implement BIM and OTL?

The process and key considerations for the successful implementation of Building Information Modelling (BIM) and Object Type Library (OTL) in road asset management. A short guide to the implementation of BIM and OTL in road asset management will be provided.

4.4.1. How to implement BIM?

Because BIM is not evidence for everyone, there can be chosen for an internal service model. This BIM team tries to support the project ingenious by implementing BIM in their public contracts. Because of this centralization and specialization, BIM is enrolled the same way in every public contract. Of course, this approach is a possible way to deal with BIM within an organization. Other ways of implementing BIM can be more effective in different kinds of organizations.

As already mentioned, BIM can be implemented in all project phases. The earlier BIM is used in a project, the more advantage that can be taken. To support the use of intelligent information models in all phases, to facilitate cooperation and to bring more uniformity to the BIM process, a BIM protocol and BIM implementation plan for infrastructure projects have been written.

The BIM protocol forms the basis for every BIM project. The general vision, guidelines and agreements in this BIM protocol are generally valid for all BIM assignments. Thanks to this basis, the necessary uniformity in BIM assignments is ensured. The project-specific implementation and practical agreements per project are further detailed in the accompanying BIM implementation plan that is drawn up per project.

When modelling the model, all the relevant BIM-data needs to be shared in a Common Data Environment (CDE). An example of such a platform is BIM360. But other software is available. On such a platform BIM-data is gathered, managed, and scattered to all parties. This makes it possible to co-work through one single platform. But it is also possible to share data from other projects that is relevant for the current project.

Besides the general rules on how BIM can be implemented, there is one major requirement for being able to do Asset Information Management: an uniform way for collecting data via BIM. Therefore, an Object Type Library (OTL) can be built. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

4.4.2. How to implement the OTL?

In the organization

To build an OTL for different technical disciplines and to elaborate the BIM guidelines for investment projects and assignments for Management & Maintenance, the OTL team needs to work closely with experts from the territorial departments and external experts. It seems obvious that asset owners are involved, when making a data standard. This approach is important for several reasons: They know best how specific assets relate to other assets, which properties are important and how to define them. Besides that, it creates a foundation in the whole organization. We don’t want to push the single truth out of an ivory tower, we want to build an OTL that is supported in the whole organization. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

In software

As already mentioned, the OTL is a data standard that is both human and machine readable. That makes that the data model can also be implemented in an organization's own software.

The OTL needs to be published via a central (data)platform, which offers access to the standards, information models, tools and documentation that enables users to get started with data and to inform them about the structured way in which it can be exchanged.

The general aim is to ensure greater coherence and better understandability and findability of information and services. That way, everyone can use and / or reuse the data more easily. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

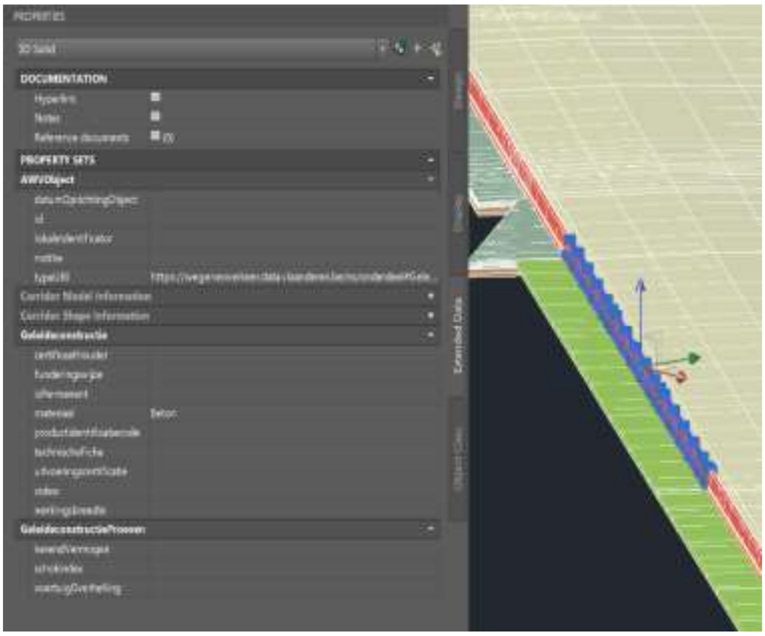

Illustration 50. library in practice (Agentschap wegen en verkeer, 2021)

4.5. LINKING TO DIGITAL PLATFORMS: BIM AS PART OF THE PLATFORM

4.5.1. Possibility to link all systems and data/information within a platform

In the field of BIM integration with other platforms or applications, there are currently road asset management systems capable of connecting with the Autodesk BIM-360 viewer. The process is briefly described below.

First, from the scan by LIDAR technology, the raw point cloud is obtained by data processing with native software. The processed file format of the scanner is a native *.LAS file. To be able to operate with this file, it is necessary to process it a second time to a format readable by the Autodesk product platform.

Illustration 51. Filtered point cloud: Autodesk Revit

Autodesk RECAP processes the selected information and creates an *.RCP file, a format readable in Autodesk platform software. The data in *.RCP format is imported into Autodesk Revit. The process of creating the 3D model of the structure is elaborated with Autodesk Revit from a lighter and clearer to interpret point cloud, imported in *.RCP format.

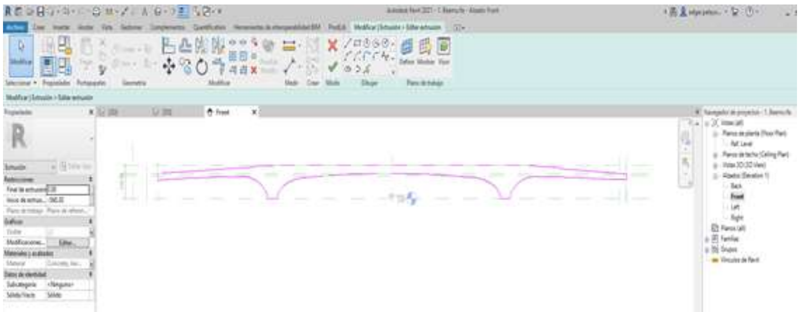

Illustration 52. Beam extrusion, front elevation: Autodesk Revit

For the creation of the elements, the reference planes must be defined both in plan and in front elevation. These help to define the geometric parameters. The rest of the elements defining the bridge were created in a similar way. The management of the information in the BIM models depends on the parameters that have been inserted throughout the design processes. The flow of information between models and agents will only be achieved if the parameters and their values have been defined correctly.

Illustration 53. Parameter assignment system families: Autodesk Revit

The last step consists of connecting the files generated with a specific asset management platform.

The conservation management work of a bridge consists of the systematic inspection of each of its elements, identifying possible pathologies, their extent and intensity. Soon these will be linked directly to 3D models that not only allow us to identify and position damage, but also to connect with the management system that will analyse this damage and its evolution to predict when it will be necessary to act, what type of action will be appropriate and the cost of this.

4.5.2. Master data management

"Master data management (MDM) is a technology-enabled discipline in which business and IT work together to ensure the uniformity, accuracy, stewardship, semantic consistency, and accountability of the enterprise's official shared master data assets" (Gartner,2022)

In an ideal situation an object type library (OTL) forms the backbone of that Master Data Model. BIM models that are started during the study of a project and that evolve further during the implementation to an as-built model are also built based on that OTL. In this way we ensure that the collected data is uniform, accurate and semantic consistent which means it can be easily transferred and reused throughout the different phases of the project. Working like this means that the successive parties (e.g. engineering firm and contractor) don't need to start from scratch but can build on an already existing model and focus on their core tasks in the project. So a "Master Data Model" is a unique data source for the management and maintenance of infrastructure. For newly performed works on the site, the as-built model forms the basic input for the Master Data Model. This model is then updated with newly generated information during the management and maintenance of the assets. Information about existing assets on the site is taken over from the existing management and maintenance applications after a thorough check. (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

4.6. Asset types for which BIM is already involved

4.6.1. Phase 1. Verification of control network

A Geodetic network comprising of the Benchmarks either recorded via GPS / GNSS or existing network benchmarks will be established by observing a static differential GPS session over all Benchmarks. The static differential GPS data will be collected over two different days utilising 2–4-hour observational sessions (dependent on baseline length). The principles of dual occupancy, redundancy and independent check will be adhered too when designing the network. Once all data has been collected the GPS baselines will be processed within TBC software and the final coordinates derived upon completion of a least squares network adjustment.

Illustration 54. Phase 1. Geodetic network.

4.6.2. Phase 2. Data collection via MMS/GPS

The data collection will be conducted utilizing either or a combination of Kinematic / Real-Time Kinematic GPS techniques, conventional survey techniques (Trimble total station), mobile mapping (Trimble MX9) and / or aerial mapping (Sensefly Ebee). The choice of which technique will be utilized will depend on the type of terrain and accuracy requirements. All GPS observations will be conducted utilizing Trimble R10/5800 dual frequency GNSS receivers linked to data loggers for automatic recording and downloading of coded observations.

Illustration 55. Phase 2. Data collection

4.6.3. Phase 3. Data processing

All surveyed data will be downloaded and processed by the field crews daily. The data will be processed each day using their specific software's and closely monitored for any errors. A few Ground Control Points should be used to check and ensure the positional accuracy of the data collected by the mobile mapping system. The type and number of GCPs will depend on the project requirement.

The GCP's will be positioned using GPS survey techniques. The Mobile Mapping System will be receiving corrections from two (2) GPS base stations, placed over official Benchmarks in direct vicinity of the site (not more than 8 km away), applying logging intervals of 1 sec. Both stations can be used for logging data and for sending corrections to roving GPS antennas for QA and data collection purposes.

Based on the mobile mapping data capture system a complete georeferenced point cloud will be derived. Above ground features will then be extracted from the point clouds, to generate basic topographic drawings of the subject project. The post processing includes site check data and equipment setup check, data output, pass to pass registration with GCP QA check, DTM classification and output, generated major break lines at ground levels, contours, annotated spot heights, extraction ground extruded features such as poles, lamps, trees, bushes from point cloud with further analysis of road camber, gradient, and the end solution of extraction of a complete model.

Regarding the processing of the point cloud data, the procedures and times vary depending on the level of detail required for the work. The following is the usual process for obtaining a basic inventory with location of elements on the point cloud, as well as the application of machine learning to automate the detection of elements such as pedestrian crossings, streetlights (illumination), or longitudinal road markings.

The results of digital readings can integrate a BIM process if they are carried out beforehand according to an adapted charter. A digital survey produced with a view to integration into a BIM model must have a level of quality defined by:

- A classification/prioritization of data (roads, vegetation, buildings, etc.) to better anticipate the model.
- An “intelligent” division to be able to use it easily for usable models.
- Adequate density and precision to project expectations.

A crucial step in the information process is the fusion of the point cloud. The point cloud of the mobile mapping must be available based on the surveyed routes, while the aerial LiDAR data must cover a large square area and the roads will be only a small part of the aerial point cloud.

The main work to be done is to merge these two-point clouds. Merging them will result in a file containing high density data around the roads. There are automatic cloud merging processes using libraries. These tools merge the information considering the vehicle trajectory and the availability of the point cloud.

The process of point cloud classification is a semi-automatic process. The semi-automatic classification of point clouds can be done for classes such as Ground, building roofs and a few other classes using tools like TScan, Global Mapper etc. This is in addition to the tools developed using Point Cloud Library. However, even after the semiautomatic method, the results would vary, and a lot of false classification would occur. These data would then be manually checked for correctness and the points would be classified to the correct groups.

Digital Elevation Models (DEMs) are a type of raster GIS layer. In a DEM, each cell of GIS layer has a value corresponding to its elevation (z-values at regularly spaced intervals). DEM data files contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the “Bare Earth”. The intervals between each of the grid points will always be referenced to some geographical coordinate system (latitude and longitude or UTM (Universal Transverse Mercator) coordinate systems (Easting and Northing). The details of the peaks and valleys in the terrain will be better modelled with small grid spacing than when the grid intervals are very large.

A digital terrain model (DTM) & Surface Models can be described as a three – dimensional representation of a terrain surface consisting of X, Y, Z coordinates stored in digital form. It includes not only heights and elevations but other geographical elements and natural features such as rivers, ridge lines, etc. & man-made features such as buildings, roads etc. A DTM is effectively a DEM that has been augmented by elements such as break lines and observations *other* than the original data to correct for artifacts produced by using only the original data.

4.6.4. Phase 4. Generation of digital elevation model, terrain & surface models

Digital Elevation Models (DEMs) are a type of raster GIS layer. In a DEM, each cell of GIS layer has a value corresponding to its elevation (z-values at regularly spaced intervals). DEM data files contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the “Bare Earth”. The intervals between each of the grid points will always be referenced to some geographical coordinate system (latitude and longitude or UTM (Universal Transverse Mercator) coordinate systems (Easting and Northing). The details of the peaks and valleys in the terrain will be better modelled with small grid spacing than when the grid intervals are very large.

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In the below pictures on the left side, we can see DEM on the left side and the corresponding DTM on the right side. We shall use tools like GlobalMapper, TModel for the generation of the DEM, DTM models. False high / spike points shall be manually checked and removed to ensure the correctness of the data.

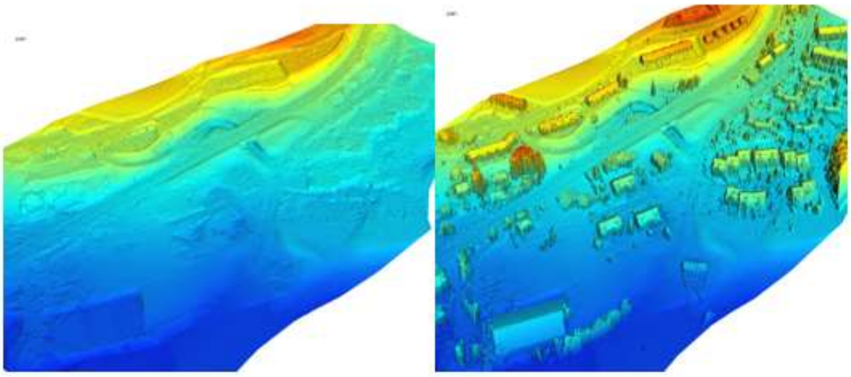

Illustration 56. DEM and corresponding DTM

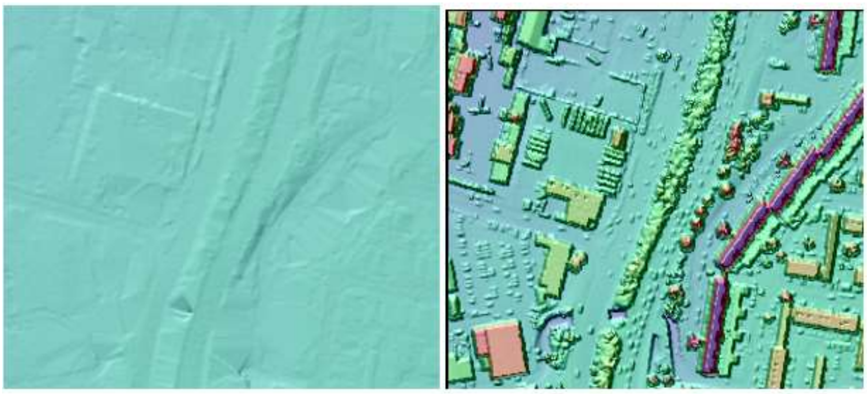

Illustration 57. DEM and corresponding DTM

The integration of both points clouds in orthometric elevations, which will include the simplification of the point cloud from the MMS and the determination, once the integration is done, of the digital terrain models (DTM) and digital surface models (MDS) high definition in the road environment. For the purposes of generating the digital models, the surfaces that comprise the strips of land indicated in the following section will be considered.

4.6.5. Phase 5. Methodology of 2D digital cortography

Once the classification has been carried out, it is necessary to have an updated cartography, in order to detect the elements to be classified. This process can be carried out manually or semi-automatically. Both methods are described below:

4.6.6. Manual Digitization

In this method the cartographer traces each line on the orthophoto and assigns the various feature class to them. Painted Linear features, road pavement area, medians etc. would be easier to identify. Information such as road marking numbers like M1.1 etc. can be assigned at the time of tracing. Objects such as signs, guard rail, poles, drainage lines etc. would be difficult to identify in this method. The markings done are then split at the junctions and assigned the corresponding section / road reference number along with other information.

4.6.7. Semi-Automatic Feature Extraction of 2D Cartography

Automatic / Semi lane detection, identification of road markings are a important topic of research that data scientists and researchers are trying resolving in the recent past. Identification of various assets on a road is an essential factor in providing satisfactory results in geospatial solutions and applications are using aerial imagery for the same.

A common technique is the use of Neural Networks / Machine Learning (ML) to identify road features and classify them. The diagram below lists the different phases involved in a typical ML process.

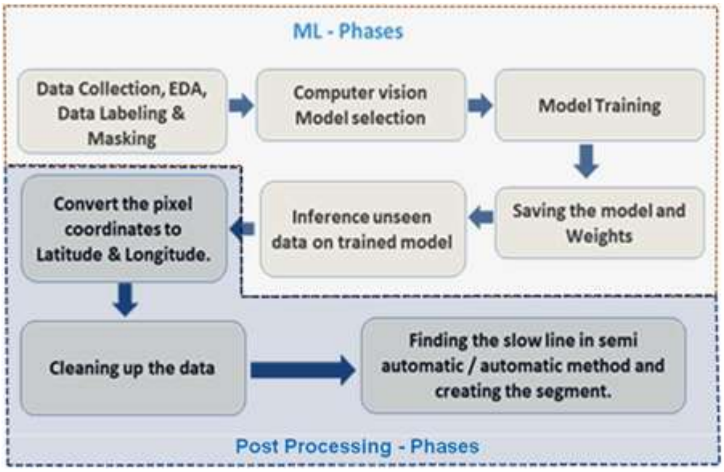

Illustration 58. Machine Learning process

4.7. TASKS, RESPONSABILITIES, SKILLS AND ORGANIZATIONAL CHART

The tasks and responsibilities described below are listed on behalf of the contracting authority and the other project partners. It concerns the project-specific BIM-related tasks and responsibilities, which complement the traditional obligations of each party involved.

The following tasks and responsibilities apply to both the procurer and any other project partner within the project:

- Place your own documents/models on the CDE.
- Cooperate and contribute to the drafting and/or updating of the BIM implementation plan.
- Comply with the agreements from the BIM protocol and the BIM implementation plan.
- Ensure that the BIM protocol and BIM implementation plan is included in the contracts of co-financiers or subcontractors so that all members of the project team can adhere to them.

- Participate in and possibly organize BIM-related meetings in accordance with chapter 9.3 and implement the action points agreed at that meeting.
- If applicable: set up, organize, and manage common platforms within the CDE according to the BIM implementation plan.

4.7.1. Contracting authority

BIM manager

The BIM manager's responsibilities include:

- Ensure that the BIM goals, requirements, and preconditions in a project are clearly defined.
- Preparing the BIM aspects in the specification texts that are necessary to achieve the desired BIM goals and requirements.
- Making the necessary practical agreements with the various partners in the project.
- Monitor uniformity regarding BIM throughout the organization and collaborate with all internal and external stakeholders to increase support and awareness of BIM.
- Actively participate in the decision-making process throughout the project. The BIM manager must answer BIM questions within a reasonable period and make BIM choices that determine the further course of the project's BIM process.
- Approving the BIM implementation plan.
- Supporting the project team of the procurer.
- Follow up and control the application of the BIM protocol and BIM execution plan.

BIM advisor

The BIM advisor has the following responsibilities, among others:

- Supporting the BIM manager.
- Monitor the coherence and IT-technical side of the BIM story.

4.7.2. Project partners

BIM project manager

The BIM project manager of each project partner steers the BIM process of that project partner in the right direction. His responsibilities include:

- Updating the BIM implementation plan throughout the project.
- Follow up and control the application of the BIM protocol and BIM implementation plan.
- Follow up, check and report on the quality and efficiency of the BIM process.

The following tasks are not part of the tasks of the BIM project manager (non-exhaustive list):

- Prepare the different BIM models.
- Make changes to the models.
- Extract the required information outputs from the models.

BIM coordinator

A BIM coordinator leads the overall coordination between sub-models, to support the project partners. A BIM coordinator has the following responsibilities, among others:

- Merging the sub-models, organizing, and monitoring the coordination between the different sub-models and reporting the conflicts to the parties involved.
- Perform clash and issue detections for interdisciplinary sub-models and make the results available.
- Follow up and check the application of the modelling agreements, agreements for naming and coding of files and objects.
- Verify the various sub-models.

The following tasks are not part of the duties of the BIM coordinator (non-exhaustive list):

- Coordinating the sub-models within a discipline.
- Make changes to the models.
- Extract the required information outputs from the models.

BIM modellers

The BIM modellers have the following responsibilities, among others:

- Build and share the specific BIM models with the desired LOD level in accordance with the applicable agreements from the BIM protocol and BIM implementation plan.
- Create 3D visualizations, extract 2D plans, tables, or other documents.
- Implementing requested changes (as agreed in chapter 9.2.3) in the models they have drawn up themselves.

(Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

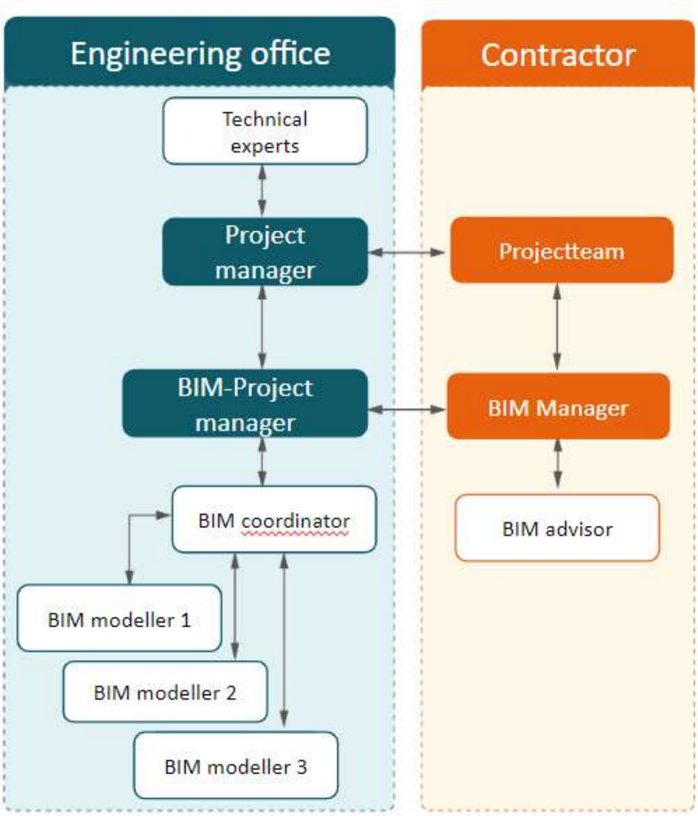

Illustration 59. Example of a BIM-organigram during study phase (Agentschap Wegen en Verkeer-Agency for Road and Traffic, 2021)

5. LMICs

The application of Building Information Modelling (BIM) and Digitalization in road asset management represents a significant opportunity for Lower Middle Income Countries in their quest to improve the efficiency and quality of their road infrastructure. These countries face unique challenges in terms of limited resources, developing infrastructure and the need to adopt innovative technologies to optimise road asset management.

In the context of Lower Middle Income Countries, the implementation of BIM and Digitalization in road asset management can offer several key benefits. Firstly, the adoption of digital technologies such as BIM can improve the planning and design of road infrastructure, enabling greater accuracy and efficiency in the construction phase. In addition, the use of BIM models can facilitate coordination between the different actors involved in the development of road projects, resulting in greater collaboration and communication.

Another important aspect is asset management throughout the life cycle of road infrastructure. Digitalization through BIM can provide a centralised platform to collect, store and manage data related to road assets, facilitating informed decision-making and long-term strategic planning. This ability to efficiently manage asset information can lead to better preventive maintenance, prolonging the life of infrastructure and optimising available resources.

Furthermore, the application of BIM and Digitalization in road asset management in Lower Middle Income Countries can foster the transfer of knowledge and best practices internationally. By integrating innovative technologies into their asset management processes, these countries can benefit from the experience and expertise of other nations, thus accelerating their development and improving the quality of their road infrastructure.

All these advantages can be seen in our case study on Mexico, which is included by the Organization for Economic Co-operation and Development (OECD) in LMIC. In Mexico, despite not being mandatory, the methodology is gaining ground in both the public and private sectors. To foster this evolution and development in this area, the government itself has been making public different strategies and measures to achieve the maximum potential in skills, capabilities and processes.

In summary, the application of BIM and Digitalization in road asset management offers lower middle-income countries the opportunity to improve the efficiency, sustainability and quality of their road infrastructure, boosting economic and social development through technological innovation in the road construction sector, which is why it would be highly recommended to promote the development of these technologies in different countries.

6. CONCLUSION AND RECOMMENDATIONS

Finally, some of the conclusions reached are briefly discussed, followed by a series of recommendations that may be very useful for the further development of these technologies in road asset management.

6.1. Conclusions

The main findings of this study have confirmed the challenges that BIM and Digitalization pose to road administrations at all income levels, as well as identifying several evidence and good practices related to the issues listed above. However, the work has also confirmed that there is a need to promote the development of these technologies in LMICs to improve road asset management, as there is not a strong presence of these technologies in these countries. We are going to name below different points of interest that we have drawn as conclusions on this subject.

Importance of Widespread BIM Adoption: Despite progress in the implementation of BIM in the construction sector, there are still significant challenges in the widespread adoption of this technology, especially among small firms. The full cooperation of all stakeholders, including subcontractors, is critical to the success of the BIM process.

Impact of the Pandemic on Research: The outbreak of the COVID-19 pandemic affected the conduct of surveys and participation in research, limiting the number of responses received. This situation highlighted the importance of adapting to changing environments and the need for flexibility in data collection.

Need to Improve Efficiency in Data Sharing: The survey results indicate that the efficiency of data sharing between units/departments within organizations is low to medium, suggesting the existence of information silos. The importance of promoting a culture of collaboration and effective data sharing is highlighted.

Financial Optimization in Asset Management: Financial optimization is crucial to maintain infrastructures in optimal condition. The ability to adjust the available budget and prioritise actions according to financial and maintenance criteria is fundamental to ensure efficient and sustainable investments over time.

In summary, it highlights the importance of adopting innovative technologies such as BIM, efficient data sharing and continuous improvement of the condition of road assets to drive sustainable development and efficiency in road infrastructure management internationally.

6.2. Recommendations

A number of recommendations have been developed to improve the development and use of these technologies, as well as recommendations for the PIARC.

Studies show that there is great potential in integrating IT systems into the prioritization, decision-making and allocation process. The introduction of IT systems would increase efficiency and reduce the influence of political factors in the asset management process.

Developing policies with the aim of promoting the development of these technologies in LMICs. Having clear policies in place to promote the development and management of quality assets ensures a consistent and effective approach to addressing the risks associated with these assets.

It is proposed to collaborate in the field of research and to link research activities in all modes of transport, but also on an international scale, and to coordinate them where appropriate, in order to achieve continuous and uniform development.

It could be a good job if the PIARC organization creates a working group for the next period which its main objective would be create models and possible standards in how to apply BIM in Asset Management. It's necessary a plan to programs how is going to coexist with traditional systems looking for the way to do the technological transition.

The different Road Agencies interested in using BIM in their Asset Management Plan should consider pilot projects as a preliminary step to BIM digitization in order to improve their development.

As a recommendation to PIARC, it is proposed that a greater focus on the collection of LMIC case studies would improve the coverage and relatability of future work on this topic.

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