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Construction Management
and Technology

DIGITAL TECHNOLOGIES IN CONSTRUCTION: USE OF VISUAL DATA AND ARTIFICIAL INTELLIGENCE FOR SAFETY AND PRODUCTION MONITORING

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A little bit of Salvador-

www.ufba.br

"Universidade Federal da Bahia is a unique site of education for human resources and knowledge production, focusing on returning to Bahia society solutions for their local issues concerning social, racial, and gender inequalities with national and international impact".

67th position among Latin American universities
17th among Brazilian universities

World University Rankings (QS)

Undergraduate
- ✓ ***Courses: 102***
- ✓ ***Enrollments: 44,015***

Graduate
- ✓ ***Courses: 150***
- ✓ ***Enrollments: 8,156***

- ✓ ***Faculty Staff: 2,876***
- ✓ ***Administrative Staff: 3,018***

Source: UFBA in numbers 2023

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Since 1897

www.eng.ufba.br

- ✓ *11 undergraduate courses in Engineering*
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- ✓ *2 Professional Master Courses*
- ✓ *5 MBA Courses*
- ✓ *Around 5,000 undergraduate students*
- ✓ *Around 1,000 graduate students*
- ✓ *183 Faculty Staff*
- ✓ *70 Administrative Staff*

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Research Areas

Performance Measurement and Benchmarking

Design and implement performance measurement systems on construction sites and companies, involving management, construction and environmental processes.

Construction Management

Develop models and methods to improve construction management, embracing processes such as planning and construction control, cost, safety as well as quality. These studies also include the use of information technology in order to improve management.

Sustainable Management in Construction

Develop studies about strategies, technologies and tools with the purpose of reducing environmental impacts in construction, especially on construction sites.

Innovation in Construction

Develop methods and models for dissemination and evaluation of the innovation management in construction, as well as evaluate emergent and information technologies in construction, such as the use of Unmanned Aerial Vehicles/Systems (UAVs/UASs) and Building Information Modeling.

Team

4 Faculty Professors
1 Pos-doc
6 PhD Students
2 Master Students
11 Undergraduate students

Close development with the industry

Implementation and evaluation of artifacts developed

Great opportunity to better investigate strategies for effective implementation, capabilities needed for the adoption of digital technologies, and AI data analysis

REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY

FEBRUARY 2017

Private Equity & Principal Investors Practice

Rise of the platform era: The next chapter in construction technology

The construction technology ecosystem is shifting toward integrated software platforms that better serve customer needs. Significant opportunities exist for strategic and financial investors.

McKinsey & Company, October 2020




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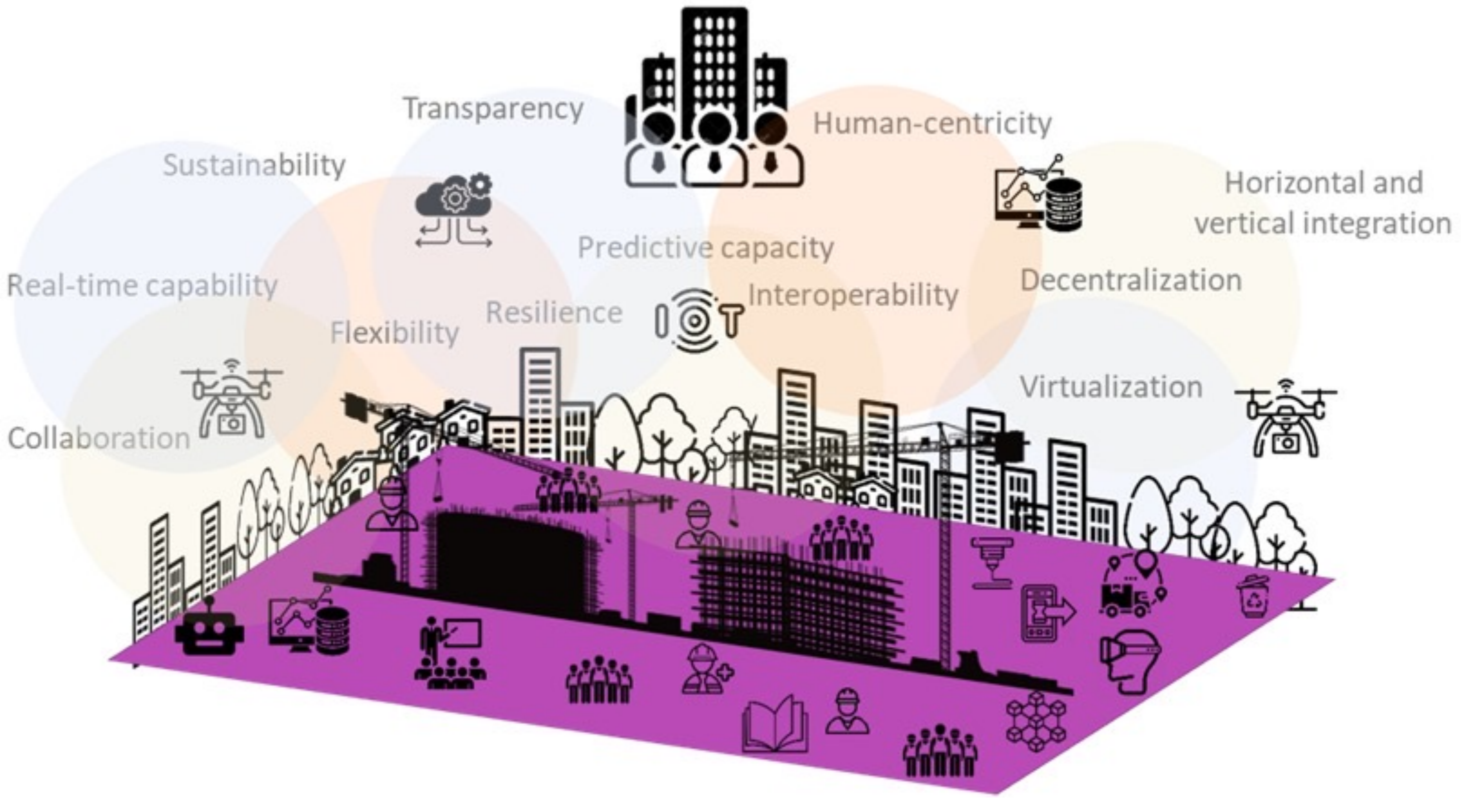
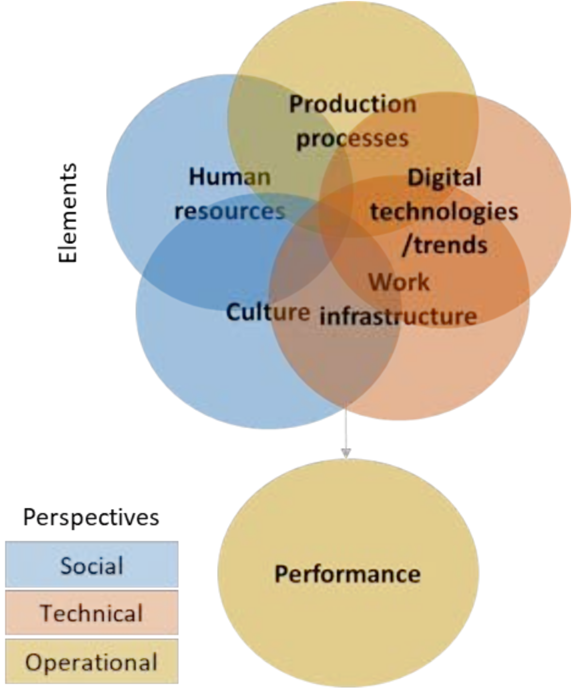
INTELLIGENT CONSTRUCTION ENVIRONMENT





Complex socio-technical system regarding the intelligent built environment

An intelligent construction environment is an efficient, resilient, human-centered, and sustainable environment composed of a complex socio-technical system that uses technologies as tools for continuous improvement. (Fernandes, 2023)

IMPACTS

- Enabling an **innovative environment**
- Improving **sustainability**
- Improving the **image of the industry**
- **Cost** savings
- **Time** savings
- Enhancing **safety**
- Better time and **cost predictability**
- Improving **quality**
- Improving **collaboration and communication**
- **Customer and end-user centric** world view

CHALLENGES

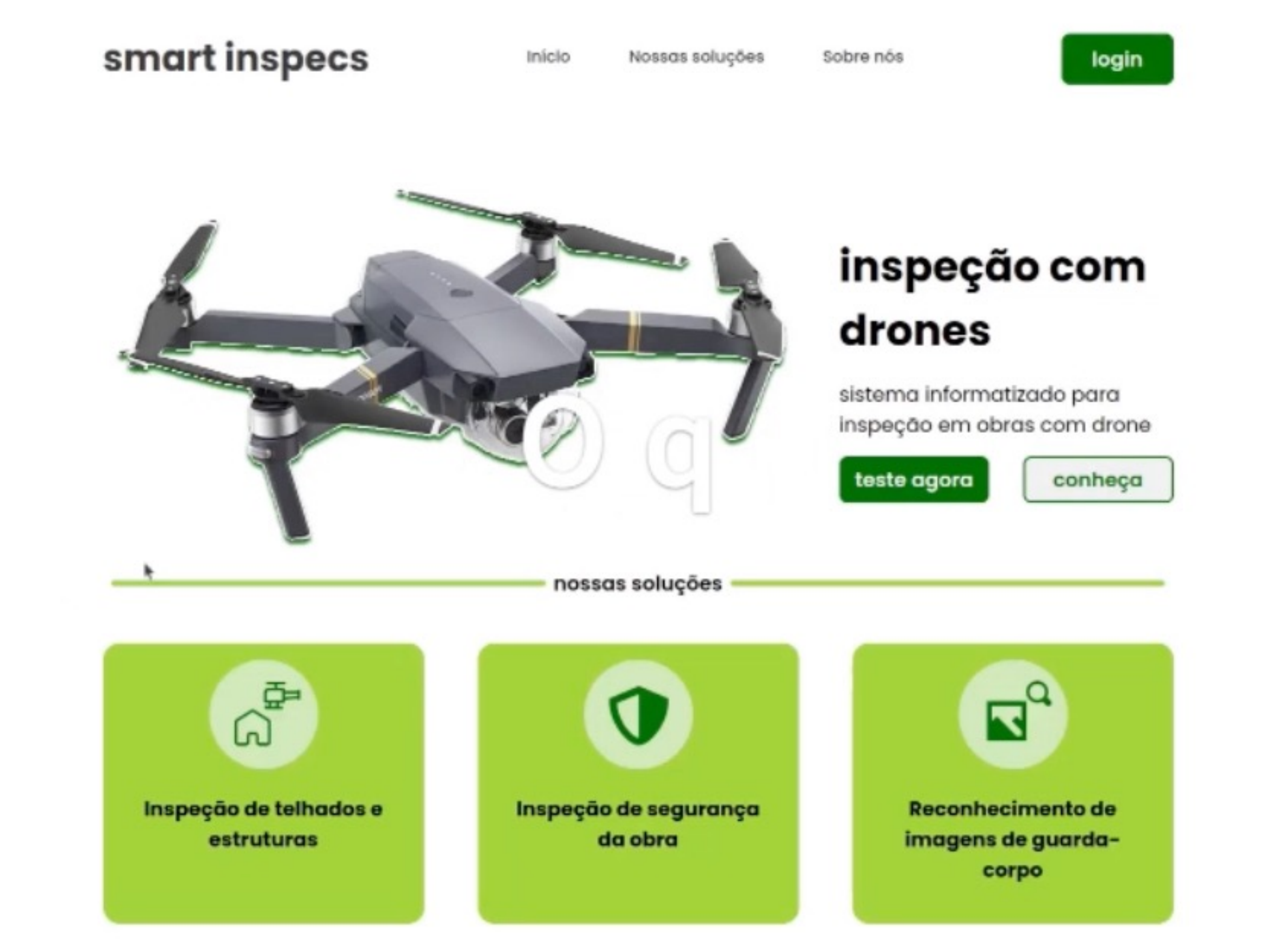
- Resistance to change
- Unclear **value proposition**
- **High** implementation **cost**
- **Low investments** in P&D
- Need for **enhanced skills**
- **Longitudinal fragmentation**
- Lack of **standards**
- **Data security, data protection, and cybersecurity**
- Legal and contractual uncertainty
- Island of automation
- Ethics for data collection and decision automation

Sawhney, Riley e Irizarry (2020)

SMART INSPECS PLATFORM

Platform for construction monitoring supported by **drones, mobiles devices, BIM and Artificial Intelligence**

- SAFETY AND GUARDRAILS CONDITIONS
- ROOFS AND FAÇADE DEFECTS AND PATHOLOGIES
- PROGRESS MONITORING AND TERMINALITY



SMART INSPECS PLATFORM

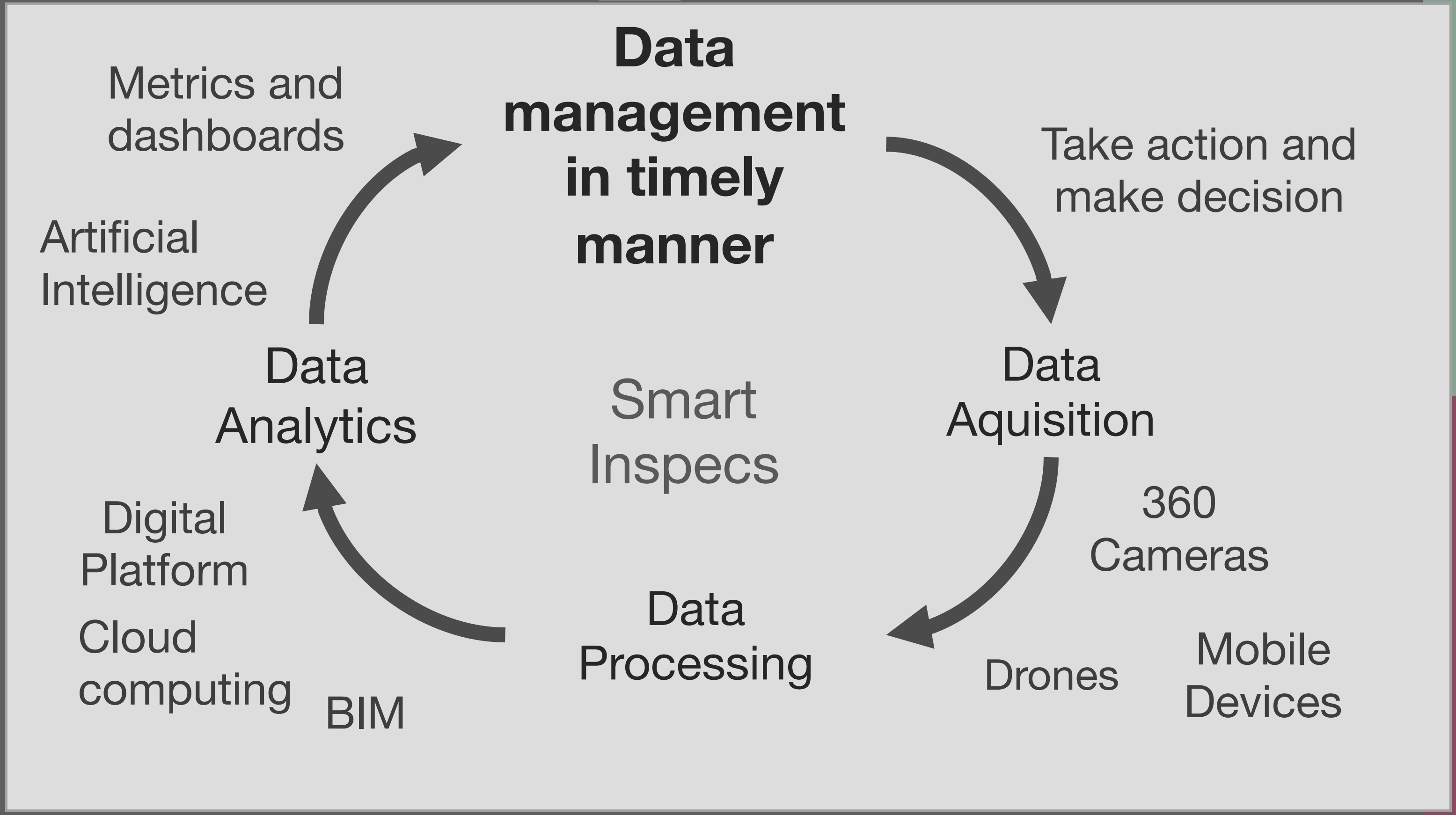
1. Project control based on visual data
2. Production management based on lean principles
3. Focus on continuous improvement

Safety and Guardrails

Conditions

Roof and Façade defects and pathologies

Progress Monitoring



SMART INSPECS JOURNAL PAPERS

Irizarry & Costa (2016)

Case Study

Exploratory Study of Potential Applications of Unmanned Aerial Systems for Construction Management Tasks

Javier Irizarry, Ph.D., M.ASCE[1]; and Dayana Bastos Costa, Ph.D.[2]

The current issue and full text archive of this journal is available on Emerald Insight at: www.emeraldinsight.com/1471-4175.htm

Exploratory study of using unmanned aerial system imagery for construction site 3D mapping

Study of using unmanned aerial system

Juliana Sampaio Álvares, Dayana Bastos Costa and Roseneia Rodrigues Santos de Melo
Department of Structural and Construction Engineering, Federal University of Bahia, Salvador, Brazil

Álvares, Costa & Melo (2018)

International Journal of Civil Engineering
https://doi.org/10.1007/s40999-020-00512-9

RESEARCH PAPER

Field Test-Based UAS Operational Procedures and Considerations for Construction Safety Management: A Qualitative Exploratory Study

Sungjin Kim[1] · Javier Irizarry[2] · Dayana Bastos Costa[3]

Received: 9 December 2019 / Revised: 26 February 2020 / Accepted: 6 April 2020
© Iran University of Science and Technology 2020

Kim, Irizarry & Costa (2020)

Recomendações e boas práticas para a integração do monitoramento da segurança com drone ao planejamento e controle da segurança de obras

Recommendations and best practices for incorporating safety monitoring with drones into safety planning and control at construction sites

Mahara Iasmine Sampaio Cardoso Lima
Dayana Bastos Costa

Lima & Costa (2023)

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

ELSEVIER

Applicability of unmanned aerial system (UAS) for safety inspection on construction sites

Roseneia Rodrigues Santos de Melo[a], Dayana Bastos Costa[b,*], Juliana Sampaio Álvares[c], Javier Irizarry[d]

Melo, Costa, Álvares & Irizarry (2017)

The current issue and full text archive of this journal is available on Emerald Insight at: www.emeraldinsight.com/0969-9988.htm

Integrating resilience engineering and UAS technology into construction safety planning and control

Integrating RE and UAS technology

Roseneia Rodrigues Santos de Melo and Dayana Bastos Costa

Melo & Costa (2019)

Safety Science 143 (2021) 105430

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

ELSEVIER

Design and implementation of a computerized safety inspection system for construction sites using UAS and digital checklists – Smart Inspecs

Rafaela Oliveira Rey[a], Roseneia Rodrigues Santos de Melo[b], Dayana Bastos Costa[c,*]

Rey, Melo & Costa (2021)

The current issue and full text archive of this journal is available on Emerald Insight at: https://www.emerald.com/insight/2398-4708.htm

Web platform for building roof maintenance inspection using UAS and artificial intelligence

Web platform

Luciano de Brito Staffa Junior, Dayana Bastos Costa, João Lucas Torres Nogueira and Alisson Souza Silva
Department of Structural and Construction Engineering, Federal University of Bahia, Salvador, Brazil

Received 3 December 2022
Revised 22 April 2023
Accepted 9 August 2023

Staffa, et al. (2023)

SAFETY CONDITIONS INSPECTION

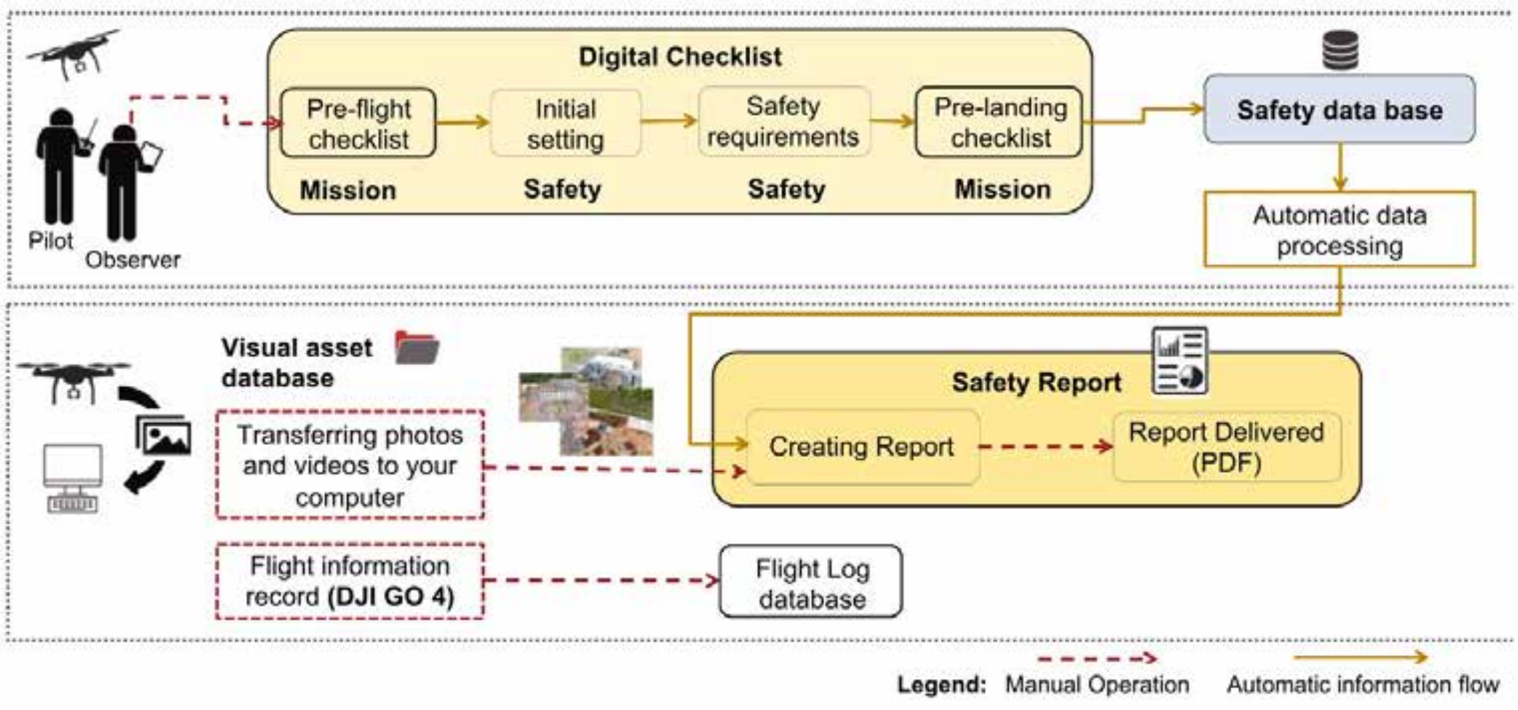


Fig. 3. Information workflow of Smart Inspecs.

Rey, Melo & Costa (2021)

PRODUCTION AND SAFETY INTEGRATION

Dashboard Analyze

Plan

Monthly and Weekly planning meeting

Do

Remove safety constrains

Check

Inspect with drone and smart inspecs

Act

Corrective action

SMART INSPECS SAFETY

- **Safety Report**
- **Action Plan**

Lima & Costa (2023)

IDENTIFICATION OF FAILURES IN GUARDRAIL SYSTEM

Types of problems in temporary guardrail systems and work platforms

Detecting Peformance: **96,8% - 97,6%**

Peinado, Melo, Santos & Costa (2023)

IDENTIFICATION OF FAILURES IN GUARDRAIL SYSTEM

- ✓ Application of data collection protocol in **3 projects**
- ✓ Training and test with *Deep Learning* <u>algorithm (ongoing)</u>

Non-existent or incomplete guardrail

Precision* = **73,0%**

Spacing between guardrail elements

Precision* = **71,1%**

Openings in the screens fixed to the panel

Precision* = **68,8%**

* Ongoing research

OUTCOMES SMART INSPECS SAFETY

- Implemented in **5 residential projects** (Out 2017 a Dez 2021)
- Currently implementing in **huge infrastructure projects** in Salvador
- More than **130 inspections**
- Average of **58 pictures** per inspection
- Average of **17,5 minutes** of flight per inspection
- Average of **1.209,25 m** distance per inspection
- Average time reduced to **25% of the initial time (2017)**
- **System Developed for the Industry**

Table 6
Average time spent during site safety condition inspection.

Activity	General Safety Condition Inspection - without system	Average time	General Safety Condition Inspection – with system	Average time
1	Image collection with UAS	20 min	Image collection with UAS and fill out the digital checklist	20 min
2	Image analysis and manual checklist fill out	90 min	Image analysis and upload the images into the report	30 min
3	Report preparation	90 min	Report delivery through email	5 min
4	Report delivery through email	5 min	–	–
–	Total time	205 min	Total time	55 min

Rey, Melo & Costa (2021)

Table 9
Workers' perception about safety inspection with UAS.

Question During the drone's flight, what is your degree of ...	Sample	Average	Standard deviation
Perception of privacy invasion	63	1.27	0.63
Distraction from working	63	1.29	0.58
Concern to hazards of falling or collision	63	1.63	1.10
Support improvement of site working conditions	63	4.48	0.90

Likert scale (1-very low to 5 - very high).

Rey, Melo & Costa (2021)

ROOF DEFECTS AND PATHOLOGIES APPLICATION

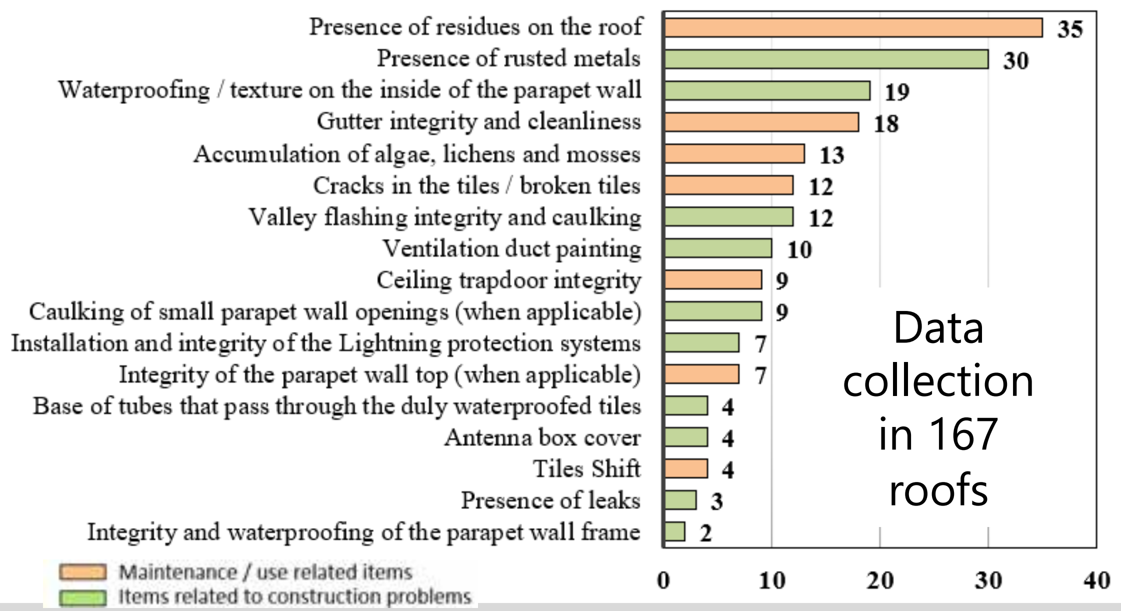
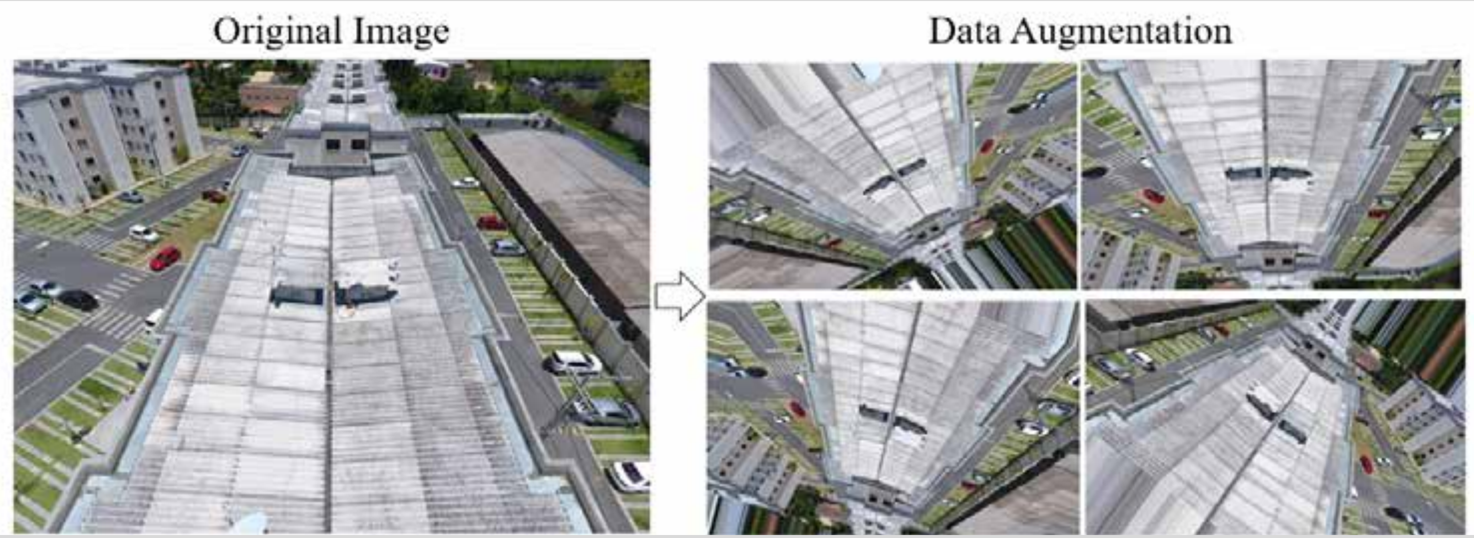


Fig. 3. Most recurring pathologies identified during all oof's inspections

Silveira, Melo & Costa (2020)

Artificial Intelligence and Data Augmentation



Staffa et al. (2023)

ROOF DEFECTS AND PATHOLOGIES APPLICATION

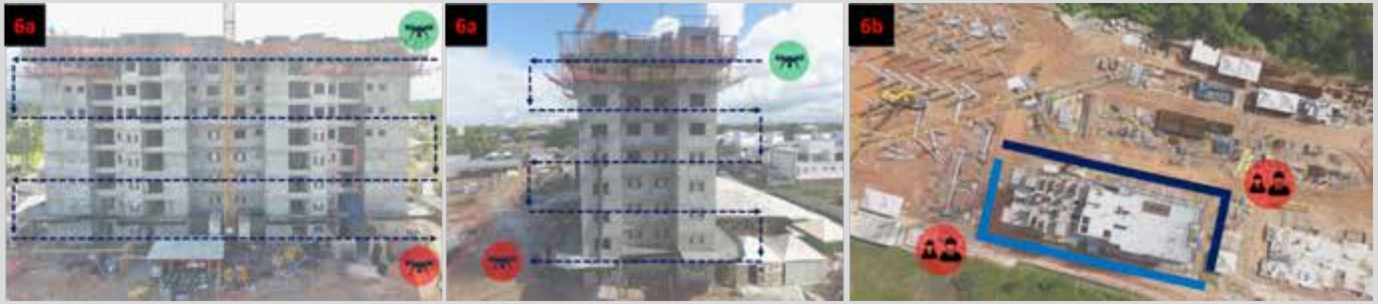
Table 2. Results of the Custom Vision model training (precision and recall)

Classes	Staffa et al. (2020)		Training 1		Training 2	
	Precision	**Recall**	**Precision**	**Recall**	**Precision**	**Recall**
Gutter cleanliness	62.10%	29.50%	**87.90%**	**39.70%**	**80.50%**	22.90%
Accumulation of algae, lichens, and mossesa	73.50%	56.80%	**81.80%**	28.10%	70.80%	19.80%
Presence of residues on the roof	82.10%	51.10%	**84.20%**	**56.10%**	**86.20%**	40.30%
Flashing's integrity	58.10%	38.30%	**83.30%**	37.00%	**87.50%**	25.00%
Gutter integrity	77.80%	43.80%	50.00%	17.60%	0.00%	0.00%
Sealing the meeting between flashings	42.90%	6.80%	**50.00%**	**9.80%**	**66.70%**	4.90%
Presence of extra tile on the roof	75.00%	66.70%	**100.00%**	**80.00%**	**90.00%**	**75.00%**
Trapdoor cover open	100.00%	57.10%	83.30%	**83.30%**	91.30%	**75.00%**
Poor fastening of the flashing	0.00%	0.00%	**80.00%**	**25.00%**	0.00%	0.00%
Proper arrangement of antennas and wires	-	-	-	-	**100.00%**	**41.20%**
Integrity of the tiles (broken)	-	-	-	-	**87.50%**	**53.80%**
Average	**63.50%**	**38.90%**	**77.83%**	**41.84%**	**69.14%**	**32.54%**

Staffa et al. (2023)

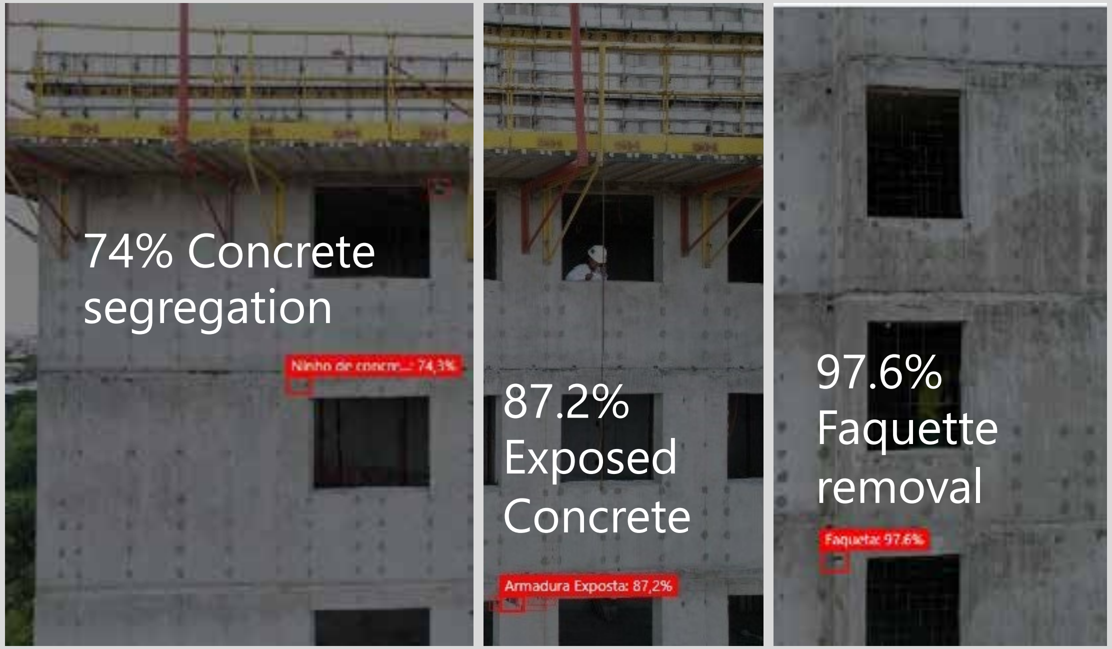
Souza (2023)

FAÇADE DEFECTS AND PATHOLOGIES APPLICATION

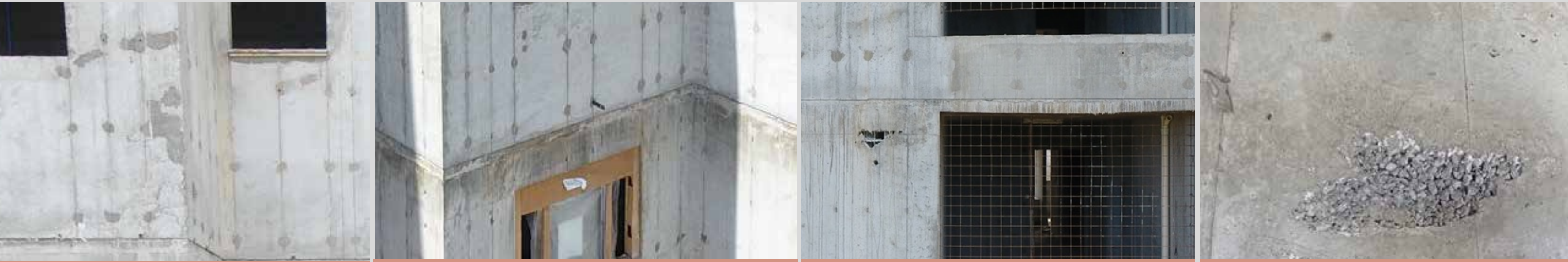


Flight trajectory performed on the four facades and Position of operators during the Flight

Probability of recognition during tests

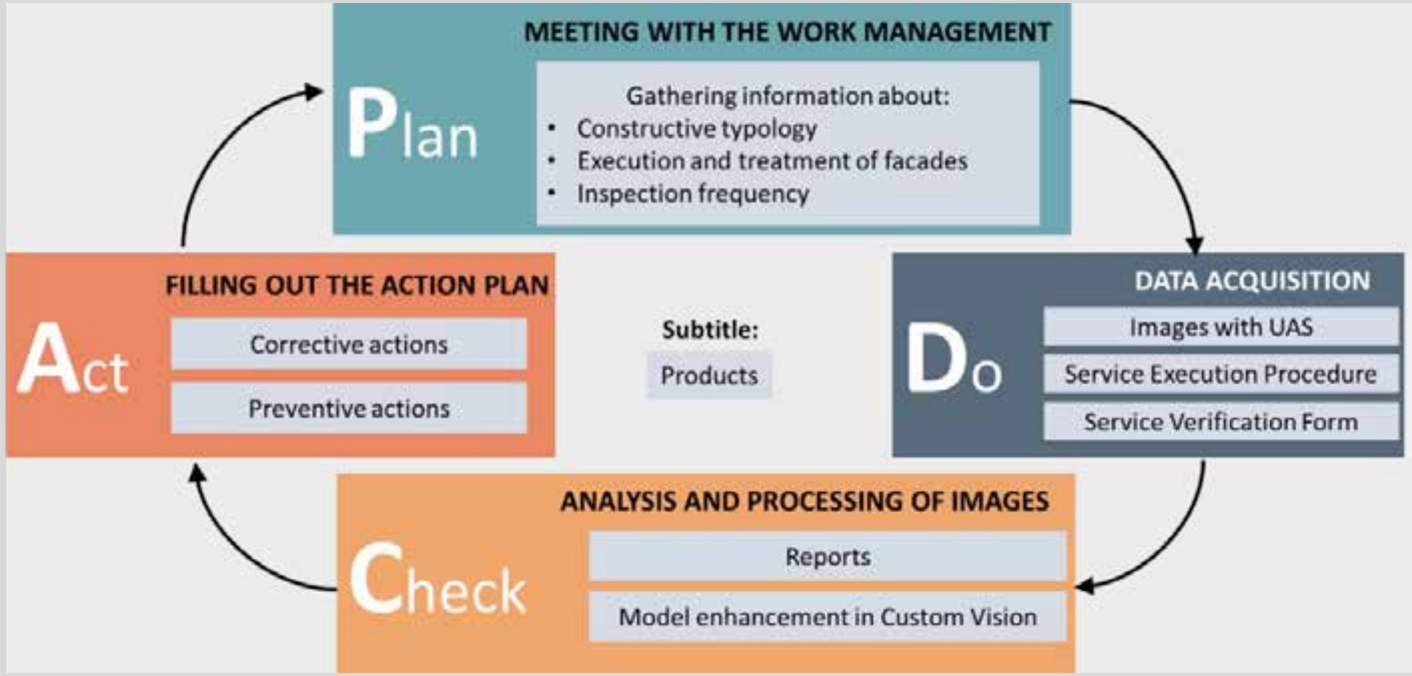


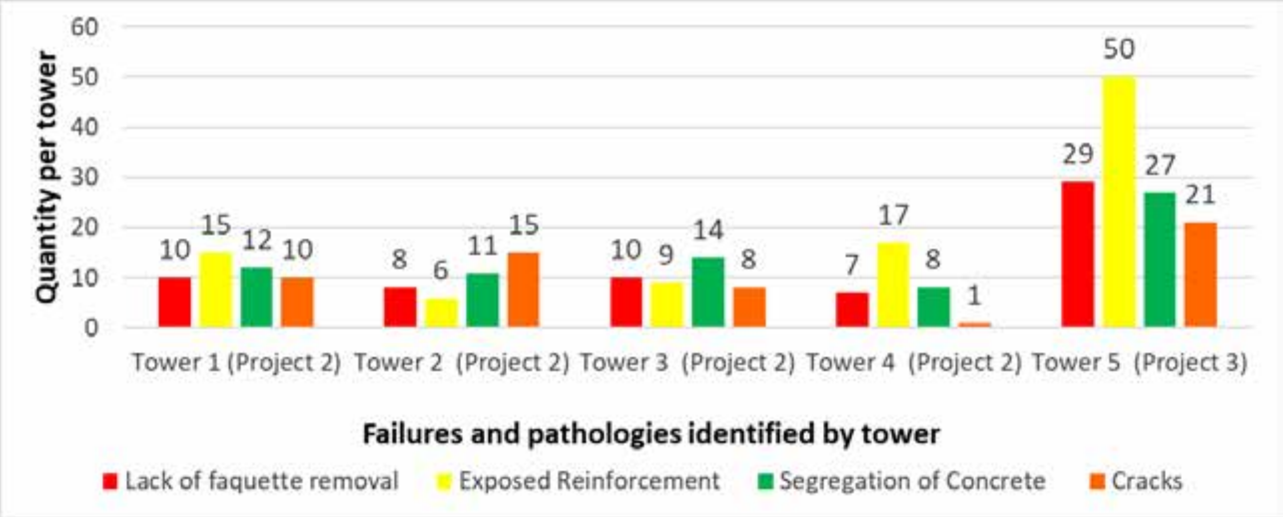
Classified defects and pathologies



Cracks | Lack of faquette removal | Exposed reinforcement | Segregation of concrete

CASE STUDY A





Souza (2023)

OUTCOMES SMART INSPECS

ROOF

✓ Implemented in **13 projects** (Aug 2018 a Dec 2021)
- **211 roofs**
- **Database with 3482 photos** and **757 photos** with defects and pathologies

FACADE

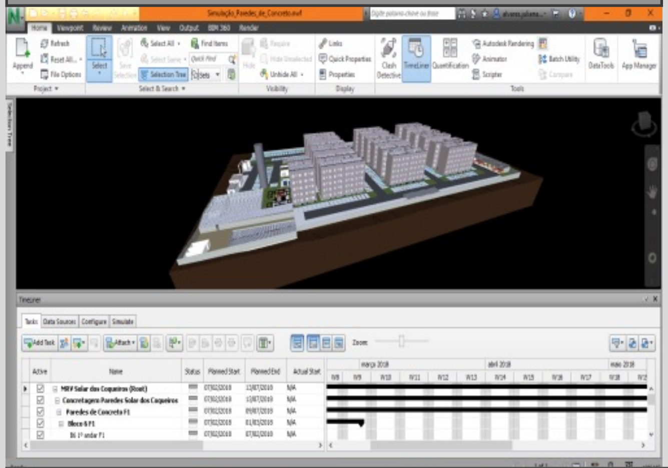
✓ Implemented in **3 projects** (Jan 2022 a Jan 2023)
- **9 towers**
- **Database with 2450 photos** and **720 photos** with defects and pathologies

Activities	**Average time per project inspection**	
	Roof	**Façade**
Image collection with UAS	26:00	34:00
Download UAS photos	01:03	02:00
Registration of the work	02:28	
Manual analysis of images and report	-	40:00
Loading and Processing of images for automatic recognition	01:56	
Automatic processing report generation	03:58	
Total time	**35:25**	**86:00**

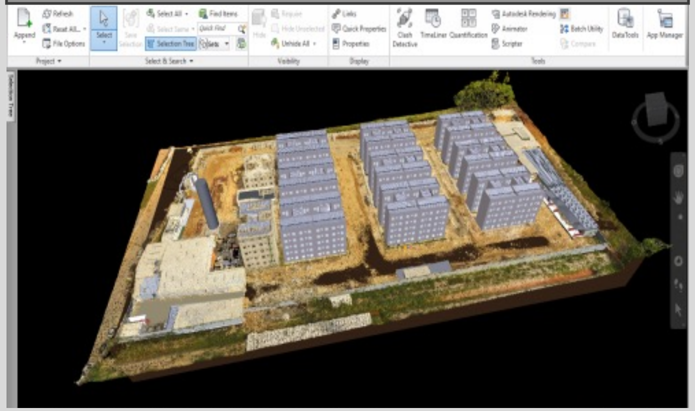
Impacts: Improving quality of roof and façade inspection, faster data collection and data recognition, and reduction of accident during inspection

APPLICATION IN PROGRESS MONITORING – EXTERNAL AREA

4D BIM model development



Overlap of the 3D as-built point cloud model to the as-planned 4D BIM model



Visual progress identification and color coding progress deviations in 4D simulations

Using Navisworks Autodesk

Table 4: The results of performance indicators over the method's implementation period – Case Study A

Month	Planned Progress (PP)	Work Progress (WP)	Work Progress Deviation (WPD)	% of the Work Progress Visually Measured (WPVM)	% of Activities Started in the Estimated Period (ASEP)	% of Activities Finished in the Estimated Duration (AFED)
April	9.59%	8.75%	**-8.75%**	**66.75%**	69.57%	30.43%
May	10.91%	10.75%	**-1.43%**	**60.18%**	77.27%	31.82%
June	12.70%	9.97%	**-21.50%**	**59.51%**	82.22%	35.56%
July	8.04%	8.51%	**5.81%**	**44.09%**	91.67%	64.58%
August	7.11%	7.66%	**7.72%**	**33.93%**	95.92%	63.27%

Progressive drop of WPVM due to the amount of inner activities in the building

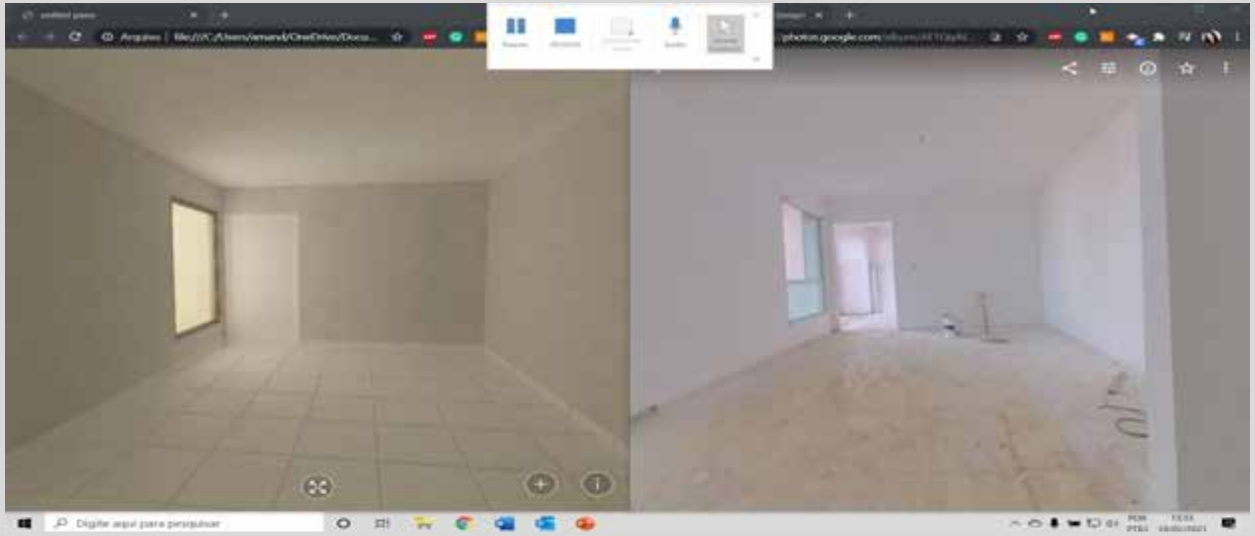
Alvares & Costa (2019)

APPLICATION IN PROGRESS MONITORING – INTERNAL AREA

360 Cameras for internal data collection

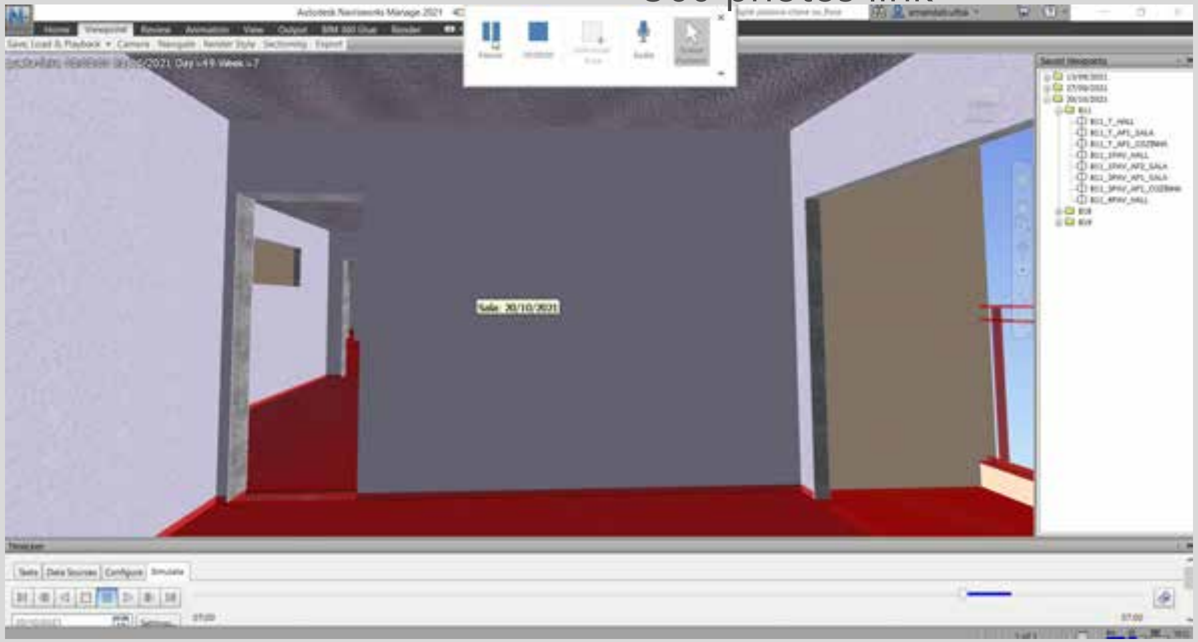
360º Camera Insta360º One X

Comparison project *as planned* (BIM 4D) and project *as built* (360 camera)



Use of viewpoints to save capture locations

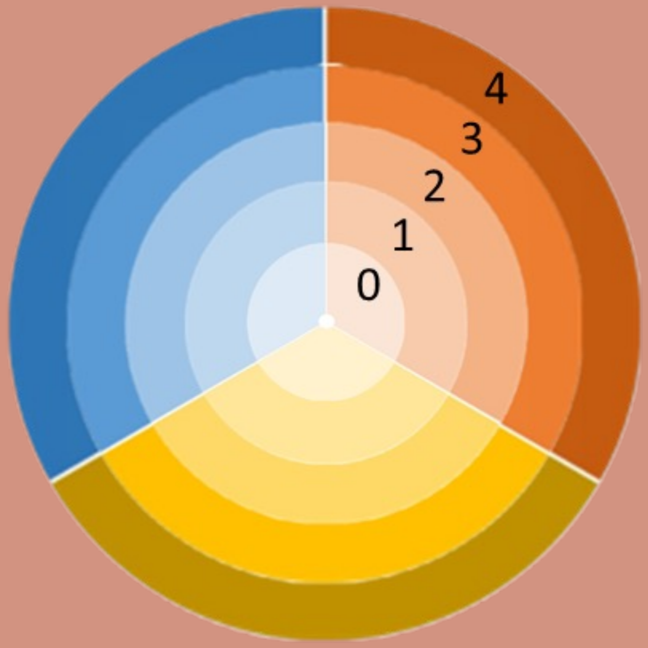
360 photos link



Good application for terminality but is too manual to process yet

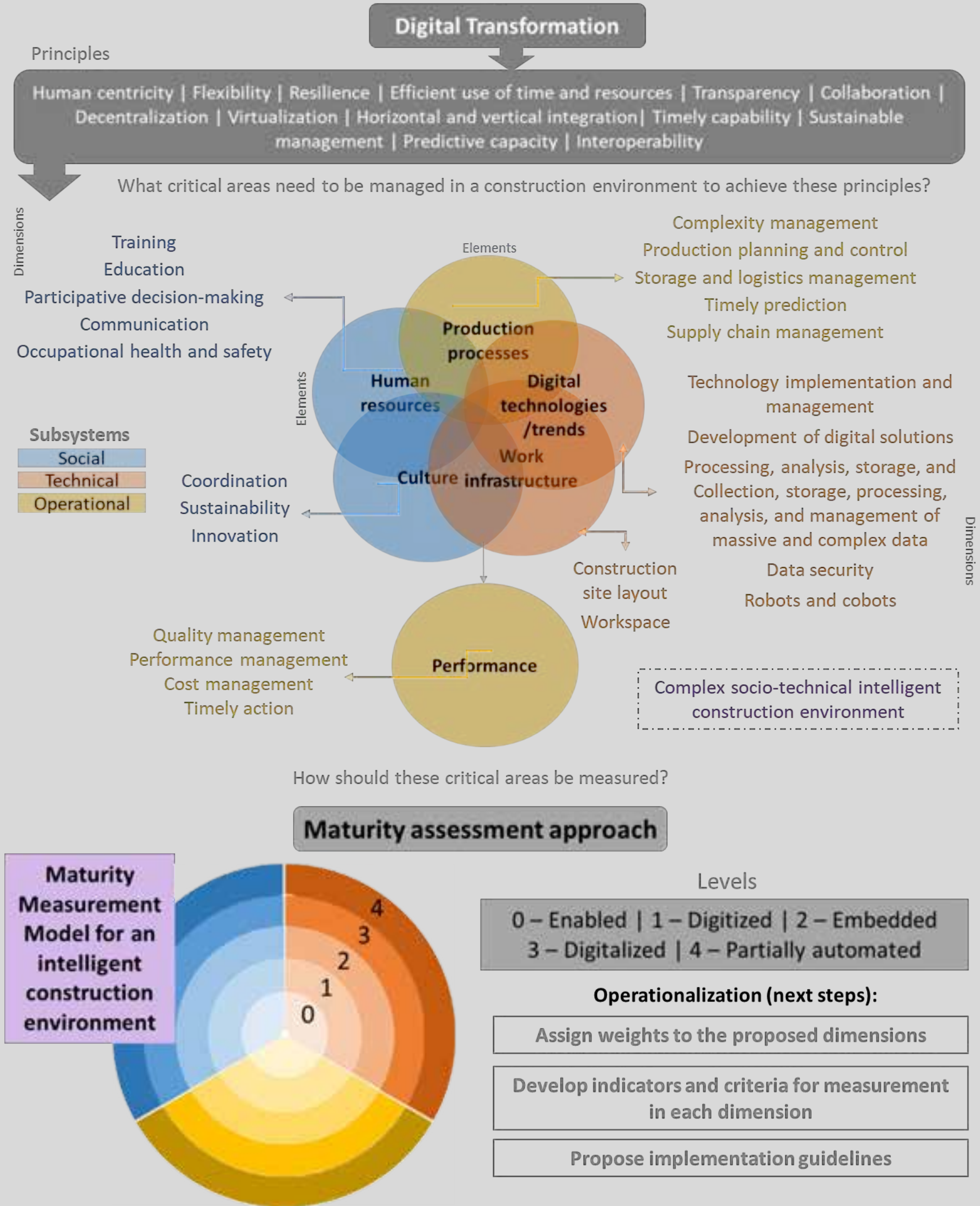
Barbosa (2022)

A MATURITY MEASUREMENT SYSTEM FOR AN INTELLIGENT CONSTRUCTION ENVIRONMENT



How the construction industry can be positioned towards digital transformation?

Maturity Models are tools to assess the effectiveness of a system and are helpful in a transformation process aimed at making something **grow from an initial to a final stage through a set of intermediate ones** (SPALTINI et al., 2022).



A MATURITY MEASUREMENT SYSTEM FOR AN INTELLIGENT CONSTRUCTION ENVIRONMENT

Data collected in the Exploratory and Case studies and the literature review provided the foundation for developing the Conceptual Model for Measuring the Maturity of an Intelligent Construction Environment.

It comprises **24 measurement dimensions** associated with **14 principles** and **five maturity levels**.

The maturity dimensions are the construction system's aspects that must be monitored and improved to achieve the intelligent construction environment principles

Fernandes & Costa (2023)

Five maturity levels

Level 0 (readiness level) – Enabling: This level position the construction system with the basic requirements to evolve into an intelligent construction environment.

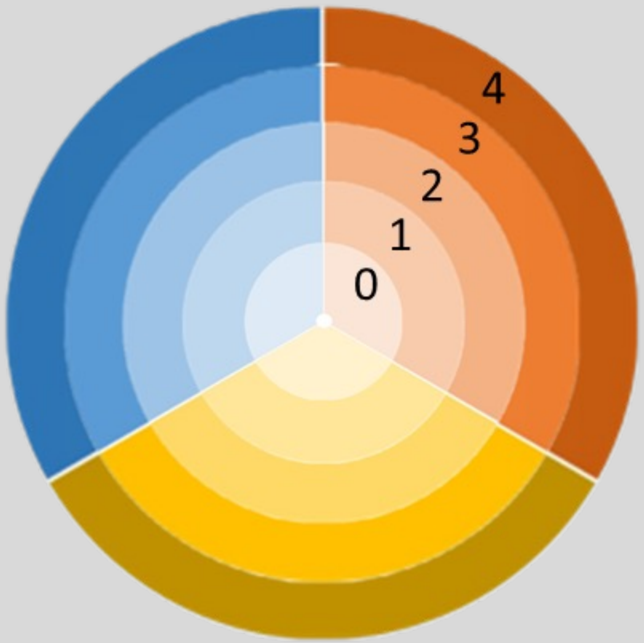
Level 1 – Digitizing: At this level, the construction system has already converted most of its critical process information to digital and implemented its first digital solutions.

Level 2 – Embedding: The level at which the system focuses on integrating the implemented digital solutions and preparing to incorporate them into the work routine.

Level 3 – Digitalizing: At this stage, digital transformation has reached all organizational processes related to the construction phase, and it is part of strategic planning, changing the business model.

Level 4 – Semi-automating: The semi-automating level presumes innovation and continuous digital transformation as company values.

Fernandes & Costa (2023)



Following steps:

- Assigning weights to the measurement dimensions.
- Proposing indicators and criteria for each dimension.
- Implementing the measurement system in four empirical studies.
- Evaluating the system from preestablished constructs and variables.

https://cbic.org.br/relacoestrabalhistas/cbic-promove-amplo-debate-sobre-questoes-de-seguranca-e-saude-no-trabalho-4/

W099 Hinze Award
Roseneia Rodrigues Santos receiving the Jimmie Hinze Award for best W099 Paper Titled: Contributions of Resilience Engineering and Visual Technology to Safety Planning and Control Process. Pictured with Prof. Billy Hare

FUTURE OPPORTUNITIES

- Advances in scaling Smart Inspecs System to be used in large infrastructure projects (safety) and university campus for facilities management (roof and façade)
- Advances in understanding how to support the construction projects with a **Maturity Measurement System for an Intelligent Construction Environment**
- Advances in **digital technology integration**
  - Digital Twins, including Scan-to-BIM, IoT, sensors, artificial intelligence, blockchain, autonomous system
- Advances in **evaluating solutions**, considering the impacts on the management process:
  - Quality of decision-making (cost, time, usability)
  - System performance (speed and accuracy)
  - User satisfaction
  - Generalization and scalability

Ongoing Research Project funded by CNPq

SMART TWINS 5.0

Digital twins aiming production and safety management integrating technologies as drones, IoT, AI, BIM and blockchain.

Professors


Dr. Dayana Costa
Coordinator


Dr. Elaine Varela


Dr. Sávio Melo


Dr. Emerson Ferreira

Post-doctoral Researcher


Dr. Roseneia Melo

PhD Candidate/Students


M.Sc. Douglas Brito


M.Sc. Luara Fernandes


M.Sc. Caroline Araújo


M.Sc. Mírian Santos


M.Sc. Hugo Peinado


M.Sc. Alisson Souza

Master Students


B.Sc. Jadi Ventin

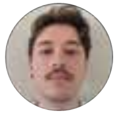

B.Sc. Vanessa Pacheco

Undergraduate Students


Caio Sousa


Carolina Andrade


Débora Piccoli


Felipe Trebino


Filipe Freitas


Guilherme Bonfim


Leonardo Gonçalves


Marcio Costa


Pedro Braga


Rafael Otávio


Salomão Souza

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CAPES
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