EPFL

The class will start at 16h15

Also part of :

E4S
Enterprise for Society

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Schweizerischer Ingenieur- und Architektenverein
Société suisse des ingénieurs et des architectes
Società svizzera degli ingegneri e degli architetti
Swiss society of engineers and architects

Innovation for construction & the environment

Dr. Dimitrios Terzis

14/10/2025

Today's class

CIVIL-424 Innovation for construction and the Environment / Fall 2025

Tuesdays 16:15-18:00 pm Lectures
Tuesdays 18:00 - 19:00 pm Project discussions and continuous reporting
Office hours: Tuesdays morning (upon email request and confirmation)

Room GRA331

			Title
Week 1	09.Sep	45 mins	Introduction to the course
		45 mins	Disruptive, Incremental Innovation and Research, Projects from last year and takeaways
Week 2	16.Sep	45 mins	Cement-free concrete
		45 mins	Cement-free concrete
Week 3	23.Sep	45 mins	Circular economy, Impact and Life Cycle Assesement
		45 mins	Sustainalytics
Week 4	30.Sep	45 mins	Harnessing renewables for buildings
		45 mins	Harnessing geo-energy for buildings
Week 5	07.Oct	45 mins	How do we digitize reality?
		45 mins	
Week 6	14.Oct	45 mins	Project preparation / Paper reading
		45 mins	Project preparation / Paper reading
Week 7	28.Oct	45 mins	Industrial innovation from the perspective of a construction giant
		45 mins	Industrial innovation from the perspective of a construction giant
Week 8	04.Nov	45 mins	Sustainalytics
		45 mins	Sustainalytics
Week 9	11.Nov	45 mins	Traffic Operations, Unmanned Aerial Systems (UAS) and Data Science for smart mobility
		45 mins	Traffic Operations, Unmanned Aerial Systems (UAS) and Data Science for smart mobility
Week 11	18.Nov	45 mins	Monitoring and surveillance
		45 mins	GIS and BIM for construction and risk management
Week 12	25.Nov	45 mins	Nature-based innovations
		45 mins	Nature-based innovations
Week 13	02.Dec	45 mins	Parametric design
		45 mins	Robotic construction
Week 14	09.Dec	45 mins	Project presentations - schedule to be announced
		45 mins	Project presentations - schedule to be announced
Week 15	16.Dec	45 mins	Synthesis of Innovation project and takeaways
		45 mins	Synthesis of Innovation project and takeaways

Today's class

1) Your continuous projects and structure
2) Tips and examples from past years
3) Value creation/perception (+business model canvas)
4) Technology readiness level

Break

1) Tips for your literature review
2) 1-to-1 feedback and planning for future follow ups

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Structure of your project

		Contents	Weighting factor
Literature review	**1.**	**Problem statement** *What problem are you solving? How big is the need to solve this problem in our field? What are some key relevant quantities in volumes/costs/damages/environmental impact?*	5%
	2.	**Current solutions overview** *What are existing solutions to tackle the above problem? Which are their main technical features? What is their level of maturity and under what conditions these solutions can be implemented?*	20%
	3.	**Use cases** *What are the use cases of the above solutions and their outcomes? What are key advantages and drawbacks/limitations?*	15%

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Problem statement in one sentence

- **Acknowledge past developments:**

Despite progress in…., there is still poor integration of ….. / the use of …. remains rather underexplored

- **Use a shift in policy/awereness or recent study:**

Recent transition towards….implies that new opportunities will emerge towards….

- **Always make reference to metrics**

Examples from past lectures

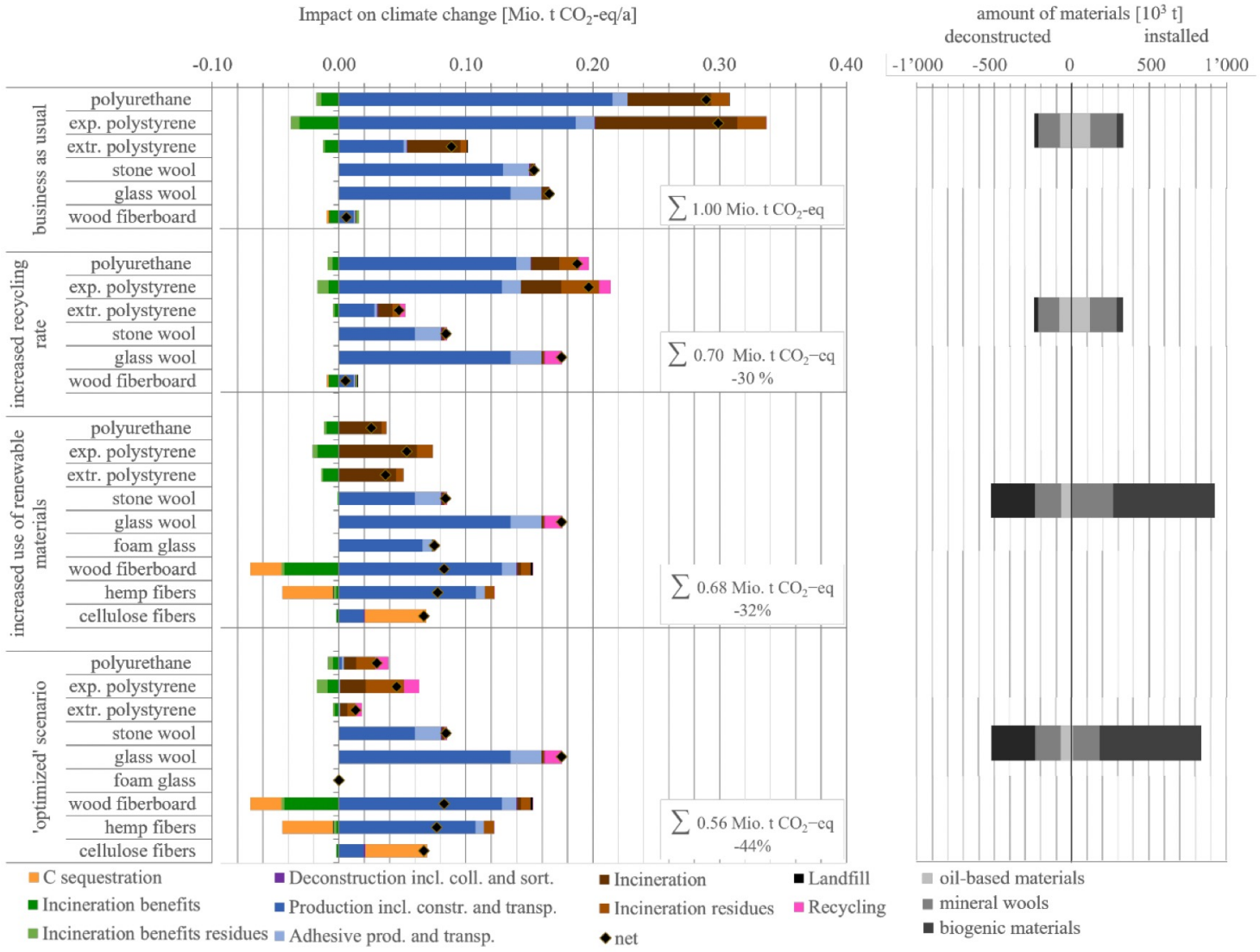

Figure 5: Left: Impact on climate change for the different scenarios 'Business as usual', (top) 'increased recycling rate' (middle top), 'increased use of renewable materials' (middle bottom), 'optimized'' (bottom) for the year 2055 on the left side. Right: the amount of insulation material installed and deconstructed for the different scenarios.

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Problem statement in one sentence

With nuclear power plants being planned to shutdown in the next decades, pressing challenges emerge towards sustainabe energy sourcing or optimizing energy use in buildings.
metrics: “a total of 27 GW in fossil fuel-fired power plants will have to be replaced within the next decade in Germany”

Despite progress in 3D printing technologies for producing building elements, the incorporation of embedded reinforcement remains rather underexplored. This is, on one hand, attributed to the complex mechanical operations involved with the printing nose/arm the associated spatial limitations. On the other hand, 3D printing is still appreciated as an early-stage technique which needs to further “prove itself” before attemtping more complex operations. The purpose of this work is to report progress in the integration of reinforcement in such elements and outline an innovative integration of XXXX and XXXX that could be beneficial for a certain range of 3D-printed elements.
metrics: XX volume per day of XX Mpa strength, significantly reduces based on the loading plane due to cold-joints, layer-by-layer printing.

Problem statement in one sentence

- “Traffic congestion costs annually CHF XXXXX.” This adds up to increasing air quality pollution, emotional distress for drivers and passengers etc.
- Regulations around flammability of buildings / recycling part of building change rapidly and question the current status-quo in materials/design and resourcing
- Custom-made cable chambers are a headache for contractors; the precast mould has to be designed and production is slow. Alternative: 3D print faster customized blocks

Paris bans cars for second day running as pollution chokes city

Vehicles with odd-number plates were banned on Tuesday and, on Wednesday, it was the even numbers' turn

Kim Willsher *in Paris*

Wed 7 Dec 2016 15.09 GMT

932 426

▲ Grey Paris: the Eiffel Tower in the smog. Photograph: Thomas Samson/AFP/Getty Images

Paris authorities restricted traffic in the city for a second day after a “lid of pollution” sealed the capital, causing concern over public health.

Photographs showed a grey veil of dirty air trapped over the city, masking the horizon and, at times, landmarks such as the Eiffel Tower. Experts said it was the longest most intense spike in pollution for at least 10 years and was expected to continue for at least another day if not longer.

Rhine River Shipping Faces Another Historic Shutdown as Drought Hits Water Levels

By William Wilkes, Bill Lehane and Vanessa Dezem | July 24, 2019

Email This | Subscribe to Newsletter

Article | 9 Comments

The bustling boat traffic on Europe's Rhine river ground to a halt for the first time in living memory last year, as shrinking alpine glaciers and severe drought made the key transport artery impassable. Those historic conditions could be repeated in a few weeks.

Bloomberg

“Lockdowns have happened recently, even before COVID-19”

Problem statement: SHM

Industry	Heavy industries	Metal industry	Vector (points)	E-PRTR (https://prtr.eea.europa.eu)	Public	2013	ci_ind_01.tif
		Mineral industry					ci_ind_02.tif
		Chemical industry					ci_ind_03.tif
		Refineries		Global Energy Observatory (http://globalenergyobservatory.org)	Public	2010	ci_ind_04.tif
	Water/waste treatment	Water and waste treatment	Vector (points)	E-PRTR (https://prtr.eea.europa.eu)	Public	2013	ci_ind_05.tif

https://www.chemengonline.com/Assets/whitepapers/Oracle_PPM_US_EN_WP_TheImpactofAgeing.pdf

It is based on a survey, conducted in September 2013, of 366 global executives in the oil and gas, utilities, chemicals and natural resource industries.

Ageing infrastructure is a headache for many industries. A substantial majority (87%) of executives report that ageing infrastructure has had an impact on their operations in recent years; one in ten say problems related to ageing infrastructure have caused severe problems in their operations that they are still trying to address successfully.

The current infrastructure upgrade spend will rise. **Almost 33% of executives say they plan to increase spending on infrastructure in the coming years, while just 8% plan to decrease spending.**

Fully 17% of executives say their companies will spend more than 40% of their operating budget on projects involving ageing infrastructure in the coming five years.

Problem statement: SHM

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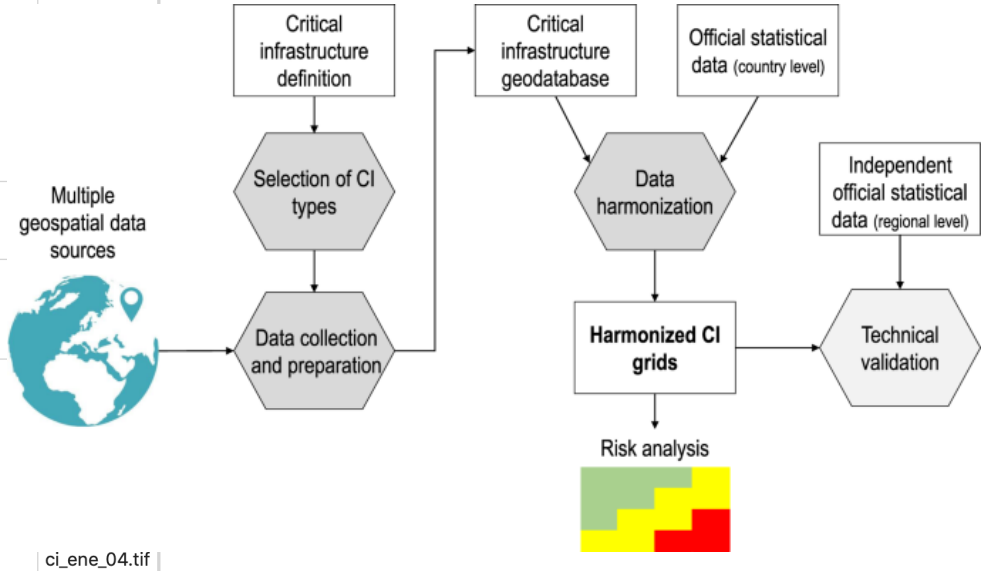
Sector	Sub-sector	Infrastructure type	Data structure	Source	Source description	Reference date	Raster filename[27]
Transport	Roads	Local roads	Vector (lines)	Open Street Map (http://download.geofabrik.de)	Voluntary Geographic Information	2014	
		Roads of national importance					
		Motorways					
	Other transport networks	Railways	Vector (lines)				
		Inland waterways		UNECE (https://www.unece.org/trans/main/sc3/maps.html) + EuroRegionalMap (https://eurogeographics.org/products-and-services/euroregionalmap)	Public (UNECE); Proprietary (EuroRegionalMap)	2013	
		Ports	Vector (points)	CORINE Land Cover (CLC) (https://land.copernicus.eu/pan-european/corine-land-cover) + EuroRegionalMap (https://eurogeographics.org/products-and-services/euroregionalmap)	Public (CLC); Proprietary (EuroRegionalMap)	2012	
		Airports					
Energy	Non-renewable energy production	Coal power plants	Vector (points)	Platts (https://www.spglobal.com/platts)	Proprietary, specialized geodatabase	2013	ci_ene_04.tif
		Gas power plants					
		Oil power plants					
		Nuclear power plants					
	Renewable energy production	Biomass and geothermal power plants	Vector (points)				ci_ene_05.tif
		Hydro power plants					ci_ene_06.tif
		Solar power plants					ci_ene_07.tif
		Wind power plants					ci_ene_08.tif
	Energy transport	Electricity distribution / transmission	Vector (lines)				ci_ene_09.tif
		Gas pipelines					ci_ene_10.tif



https://www.nature.com/articles/s41597-019-0135-1

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Data Descriptor | Open Access | Published: 18 July 2019

HARCI-EU, a harmonized gridded dataset of critical infrastructures in Europe for large-scale risk assessments

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1406 Accesses | **2** Altmetric | Metrics

Problem statement: SHM

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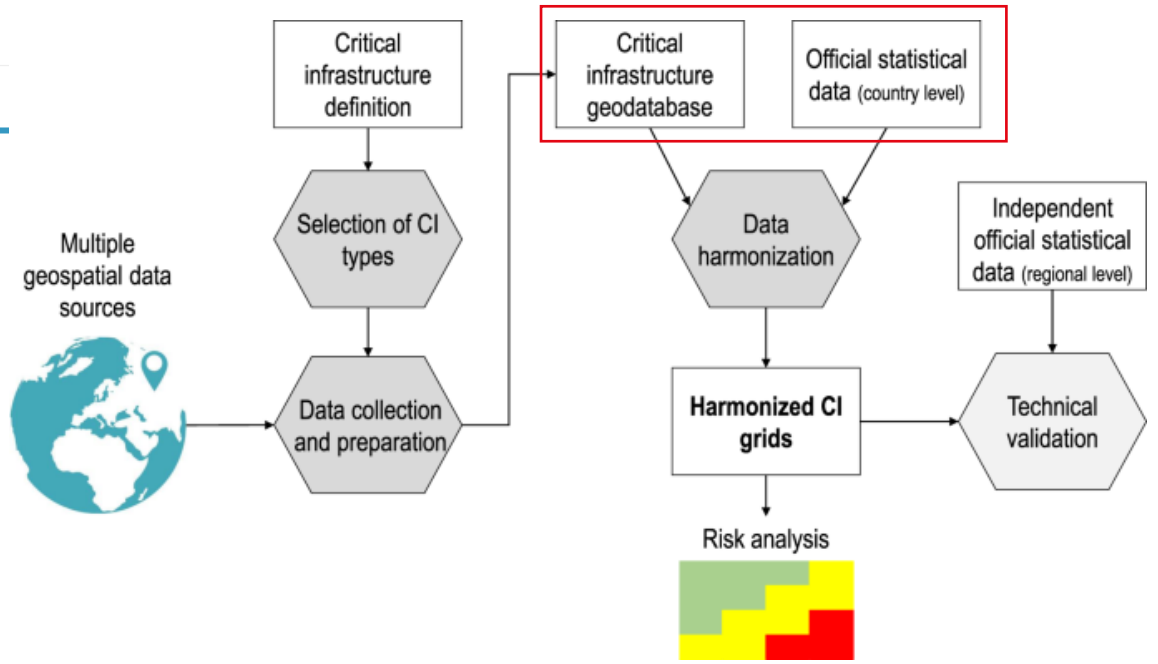

https://www.nature.com/articles/s41597-019-0135-1

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Regarding monitoring / underground infrastructure

September 2025:

The Independent

Huge sinkhole near hospital swallows cars and sparks traffic chaos

A section of a Bangkok road dramatically collapsed on Wednesday, creating a vast sinkhole that disrupted traffic, damaged infrastructure, and...

3 weeks ago

Reuters

Thailand works to tackle massive sinkhole in capital

Thailand works to tackle massive sinkhole in capital ... BANGKOK, Sept 24 (Reuters) - Thai authorities rushed to contain a massive sinkhole near a...

3 weeks ago

NBC News

Sinkhole swallows delivery truck in Mexico

Sinkhole swallows delivery truck in Mexico.

1 month ago

ETH zürich Singapore-ETH Centre

About Research Impact People Partners News & Events Resources Jobs

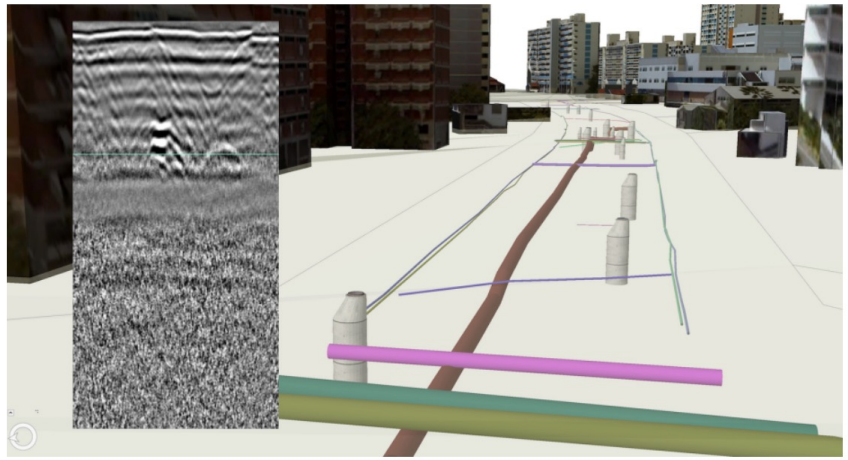
- Big Data
- Mobile ground penetration radar
- 3D modelling

Homepage > News & Events > Singapore-ETH Centre news channel > 2019 > 09 > Mapping undergrour

Mapping underground utilities in 3D

05.09.2019

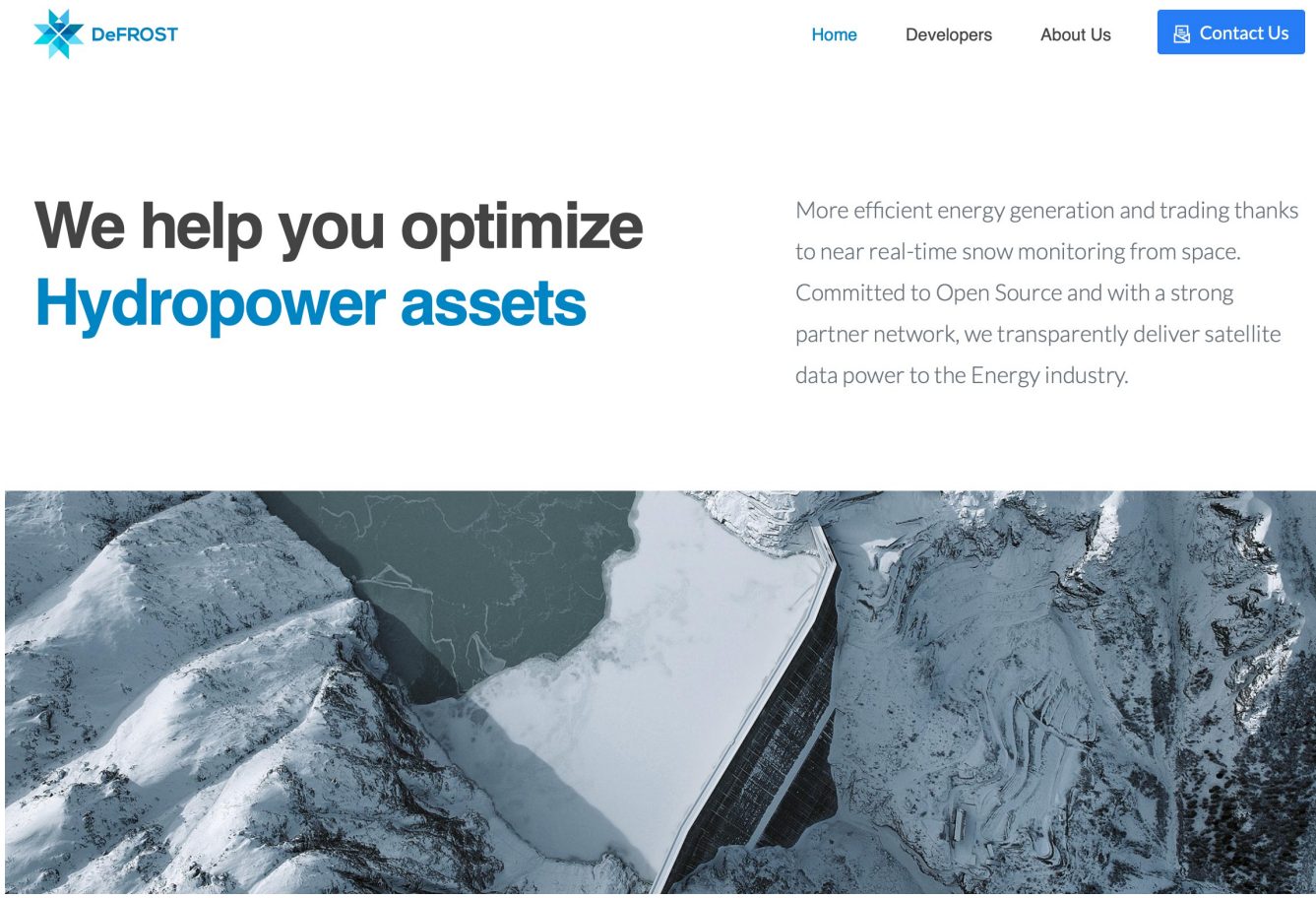
How can we map reliable 3D underground utility networks and use them in land administration? A framework for utility data goverance was published in *Remote Sensing*.



With the pressure of the increasing density of urban areas, some public infrastructures are moving to the underground to free up space above, such as utility lines, rail lines and roads. In the big data era, the three-dimensional (3D) data can be beneficial to understand the complex urban area.

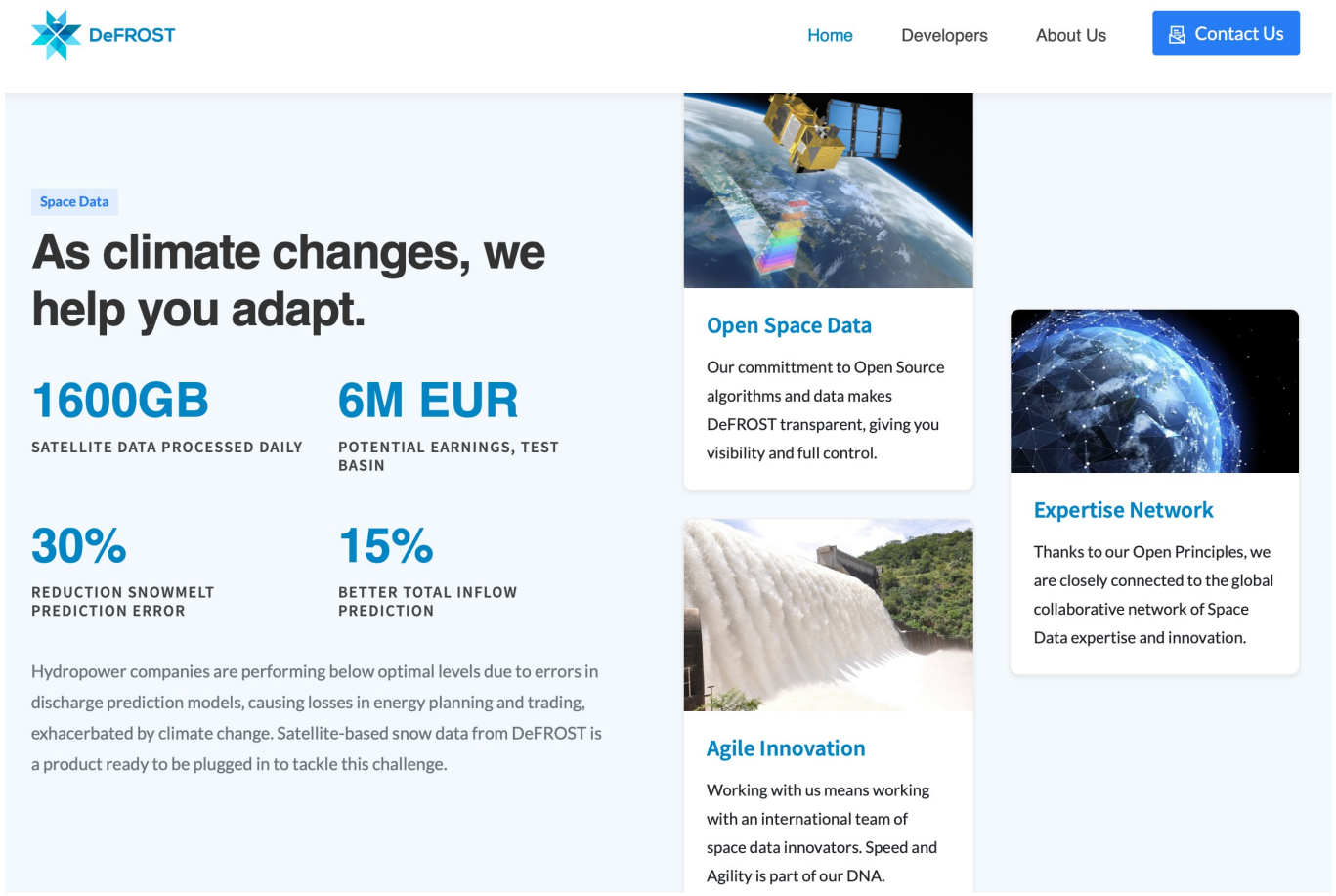
Source: https://sec.ethz.ch/news-events/news/2019/09/mapping-underground-utilities-in-3d.html

On 6-Dimensional modelling



- 3D Space
- Time
- Cost (resources management)
- Environment

On 6-Dimensional modelling



- 3D Space
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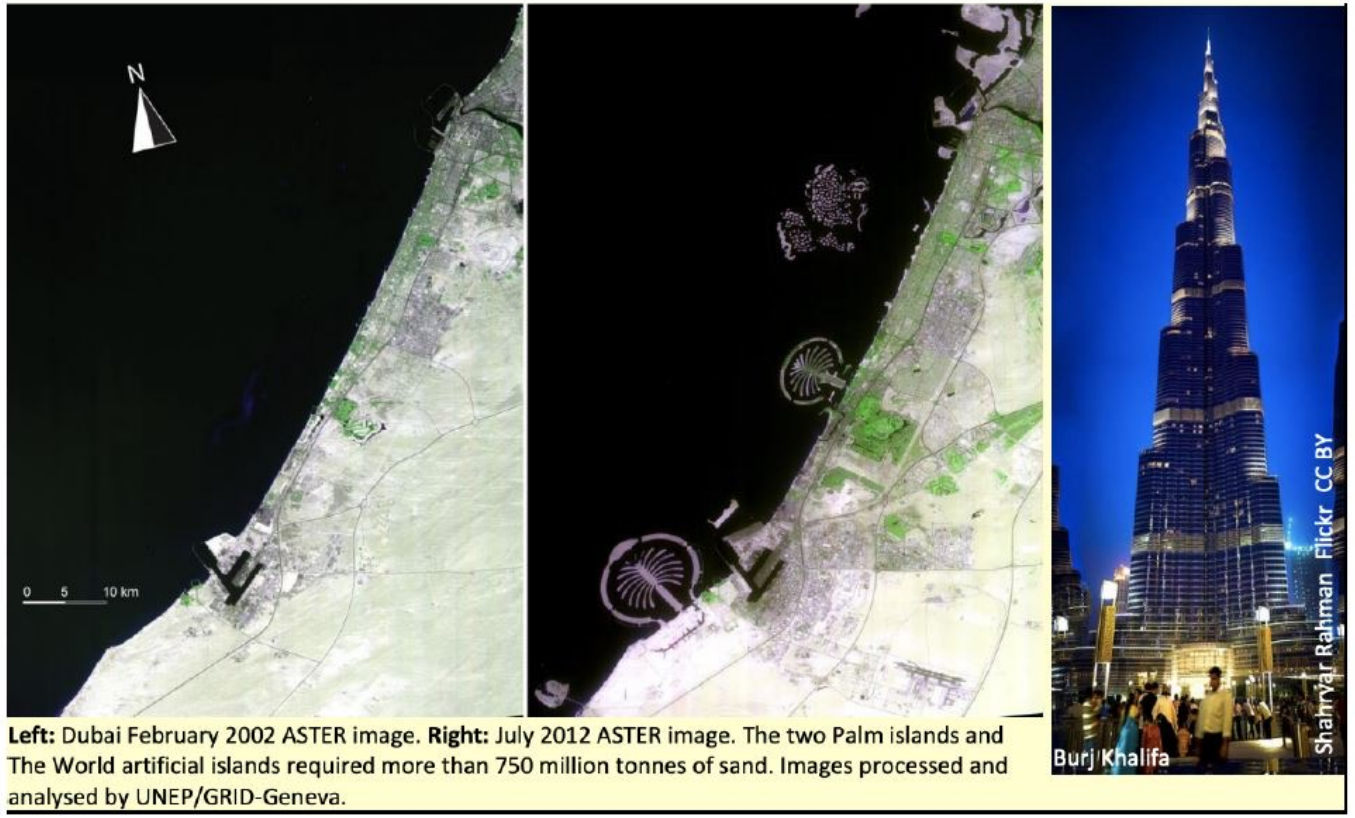
Example of project: Problem Statement



Left: Dubai February 2002 ASTER image. **Right:** July 2012 ASTER image. The two Palm islands and The World artificial islands required more than 750 million tonnes of sand. Images processed and analysed by UNEP/GRID-Geneva.

Figure 1: Image of Dubai's Islands

- Singapore 1/5 of the country is backfill.
- Dams prevent 25% of sand from reaching ocean.
- China 60% of global sand production[4].

Example of project: Problem Statement

Regarding the geographic site of sand mining in Europe, they are mainly located in Germany and France (see figure 4 below).

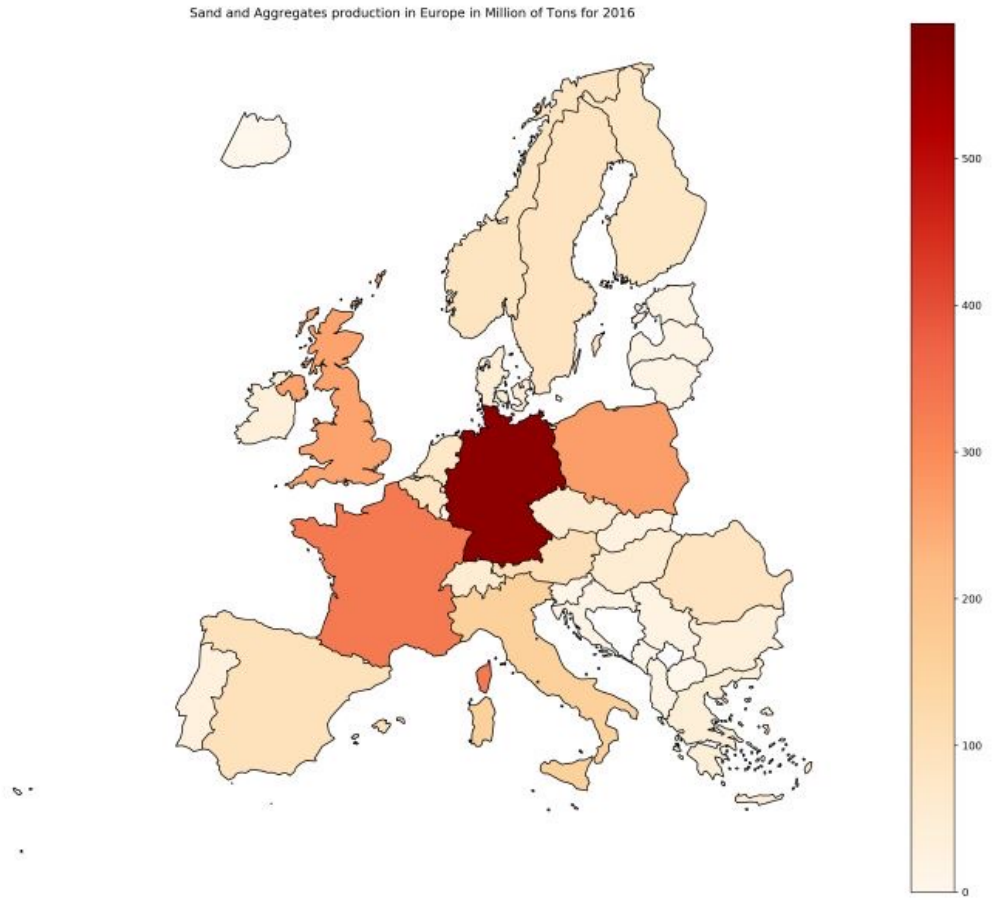


Figure 4: Production of sand and aggregates in Europe in 2016 [2]

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Example of project: Problem Statement & metrics

Example for the Vaud canton (2014) : [25]

- Construction Waste : 4'150'000 t

1. Excavation Materials : 2'900'000 t
2. Demolition Waste (Minerals): 1'035'000 t
3. Other Demolition Waste : 215'000 t

The mineral demolition waste are the concrete obtained during the demolition or milling of reinforced or unenforced structures and pavements; the bituminous road demolition materials resulting from the milling or demolition of bituminous pavement; the non-bituminous road demolition materials resulting from the demolition of unbound base layers, free of substances such as concrete, bituminous materials, bricks or roof tiles. They are assimilated to natural gravel, provided that at least 95% of them are composed of it.

From the 830'000 [*tonnes*] recycled, 740'000 [*tonnes*] were taken by some specific companies who valorize the waste in some specific demolition waste management plant and only 90'000 [*tonnes*] were crushed and valorized on site.

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Structure of your project

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Example of project: Overview of current solutions & Use cases

A good starting point would be to look for examples and for cases where construction and demolition wastes were reused on site to produced recycled concrete. One example was found in Geneva, on one of the construction site where a tunnel was dug for the CEVA (Regional train in Geneva Area). The company Marti SA installed a centrale on the working site allowing an in-situ recycling of materials. The excavated materials when the tunnel is dug are crushed, washed and sorted before being used in the concrete. With this system[18] :

- 200'000 $[m^3]$ of excavated materials were not put into landfill
- 270'000 $[tons]$ of aggregates were produced on site
- 200'000 $[km]$ were less traveled on the road to deliver the aggregates or removed the excavated materials

Example of project: Overview of current solutions (more metrics!)

3 Substitution, solution to the problem ?

As previously explained, the concrete is one of the main issues concerning sand use worldwide. We shall find new ways to produce cement or concrete in an efficient way (keeping its strength, permeability, properties) using less and less sand. We will in the following sections propose different ideas and researches done in that direction and present the outcome and the results of these studies.

Each solution may apply to one specific aspect of the construction field (cement, roads, etc ...) and we need to keep in mind that, sand may not be entirely replaced but, combining these alternatives and partial solutions may reduce significantly our needs.

3.1 Stone Ash

One of the partial solution we could propose is the stone ash. Stone ash is "the result of processing broken stones using stone crusher" [11]. Therefore, this resource is likely to be present in large quantities and could be considered as a good replacement. Once mixed into the cement, it would preserve the concrete strength as if sand was used.

Based on a report from the Indonesia Malaysia Research Consortium Seminar [11], we were able to find how stone ash would affect the strength of concrete once integrated in the cement production. The results of the study are shown below, in table (1).

Percentage of stone ash	Concrete compressive strength [MPa]	Strength reduction [%]
5%	39.37	0.63
10%	38.32	1.68
15%	37.38	2.62
20%	36.28	3.72

Table 1: Results from test of stone ash in cement for $f'_c = 40$[MPa] concrete [11]

Example of project: Overview of current solutions (more metrics!)

Technology	Field	Description	Reliability
Stone ash	Replacement	Using aggregate to be mixed with concrete without loosing strength	✓
Sand desert	Replacement	Using desert sand for temporary events	X
Plastic waste	Replacement	Using recycled PET from households in roads construction	≃
Recycled concrete	Replacement	Using concrete from demolition site, crushing it to have new aggregates/sand	✓

Example of project: More use cases

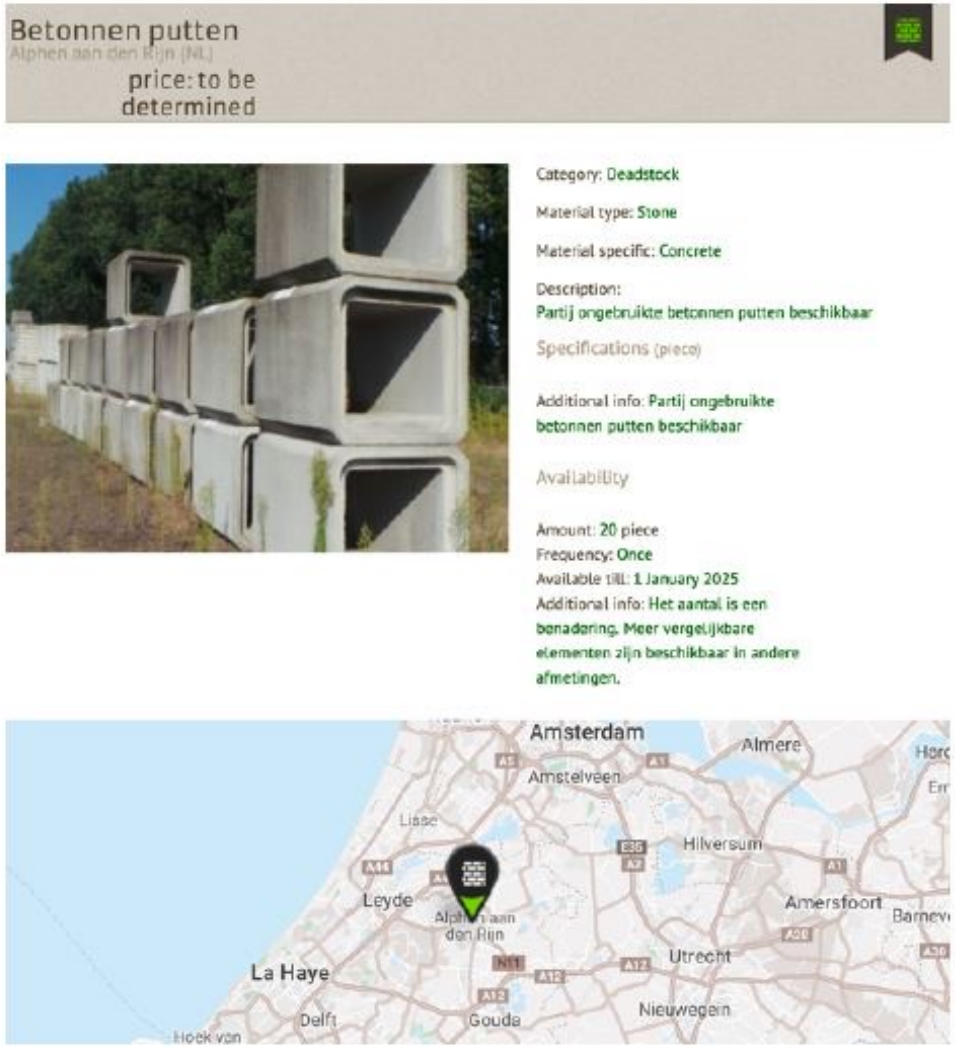

Figure 12: Example of a digital marketplace of re-usable material

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Structure of your project

Innovation and impact creation	**4.**	**Room for innovation** *Have you identified opportunities to innovate and if yes what lies in the core of studied innovation (hardware/software/infrastructure?)*	25%
	5.	**Value creation** *Who benefits from your studied innovation? What is the value you create and for which partners? Who do you depend on and who depends on you (regulations, technology manufacturers, service providers etc)? You can use elements of your business model canvas to facilitate this section*	20%
	6.	**Potential Risks** *Have you identified any potential risks or barriers from regulations or competition from existing solutions? Are there any technological limitations that could hinder your studied innovation?*	5%
	7.	**Impact created** *What is the created environmental/societal/economic impact of your studied innovation?*	5%
	Overall quality of presentation and of used references from literature.		5%

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Example of room for innovation: databases

What already exists for the city of Geneva is a three-dimensional numerical map of existing buildings (grey) and those planned or under construction (purple). An extract from this platform is shown in figure 15.

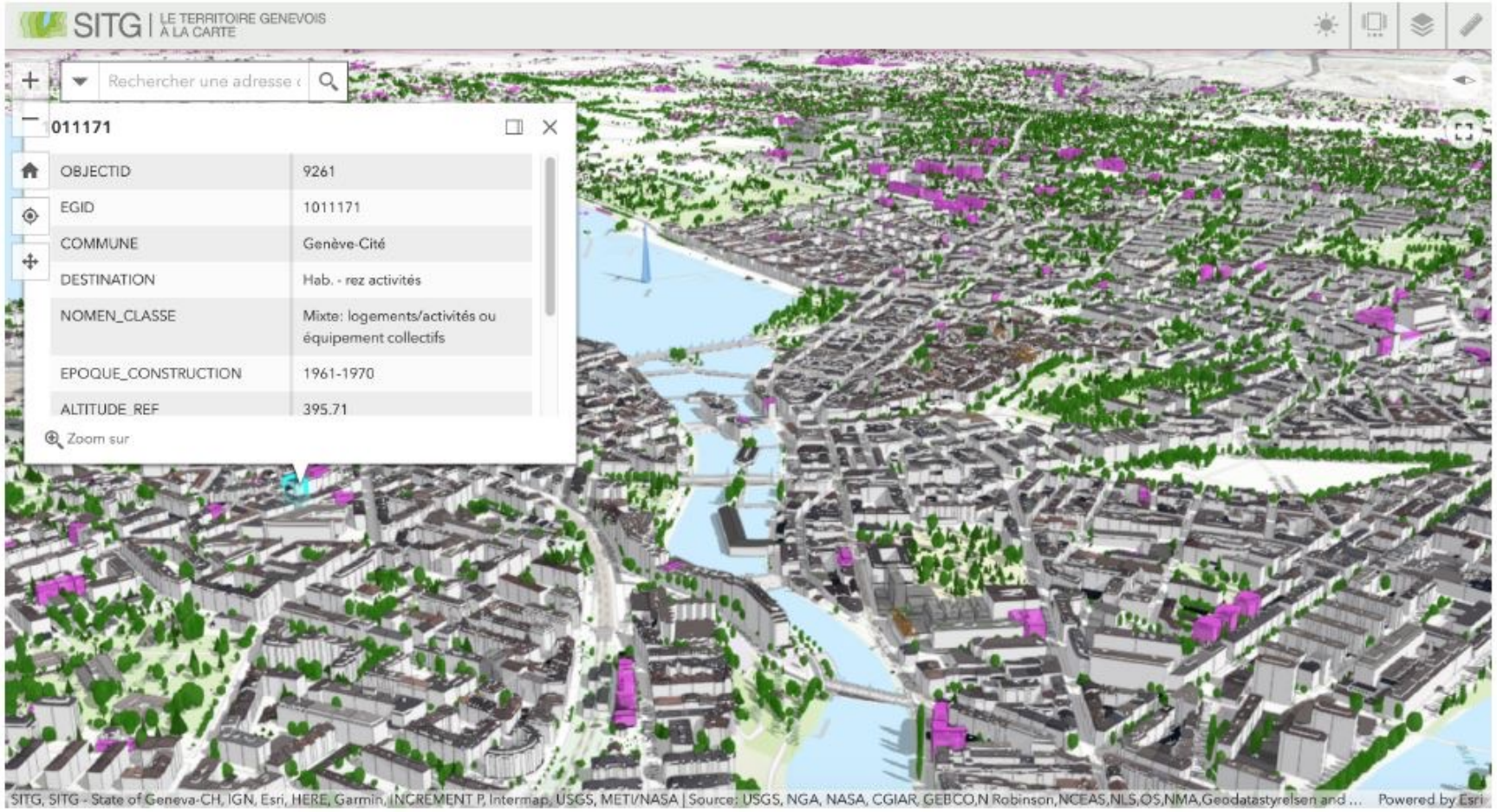
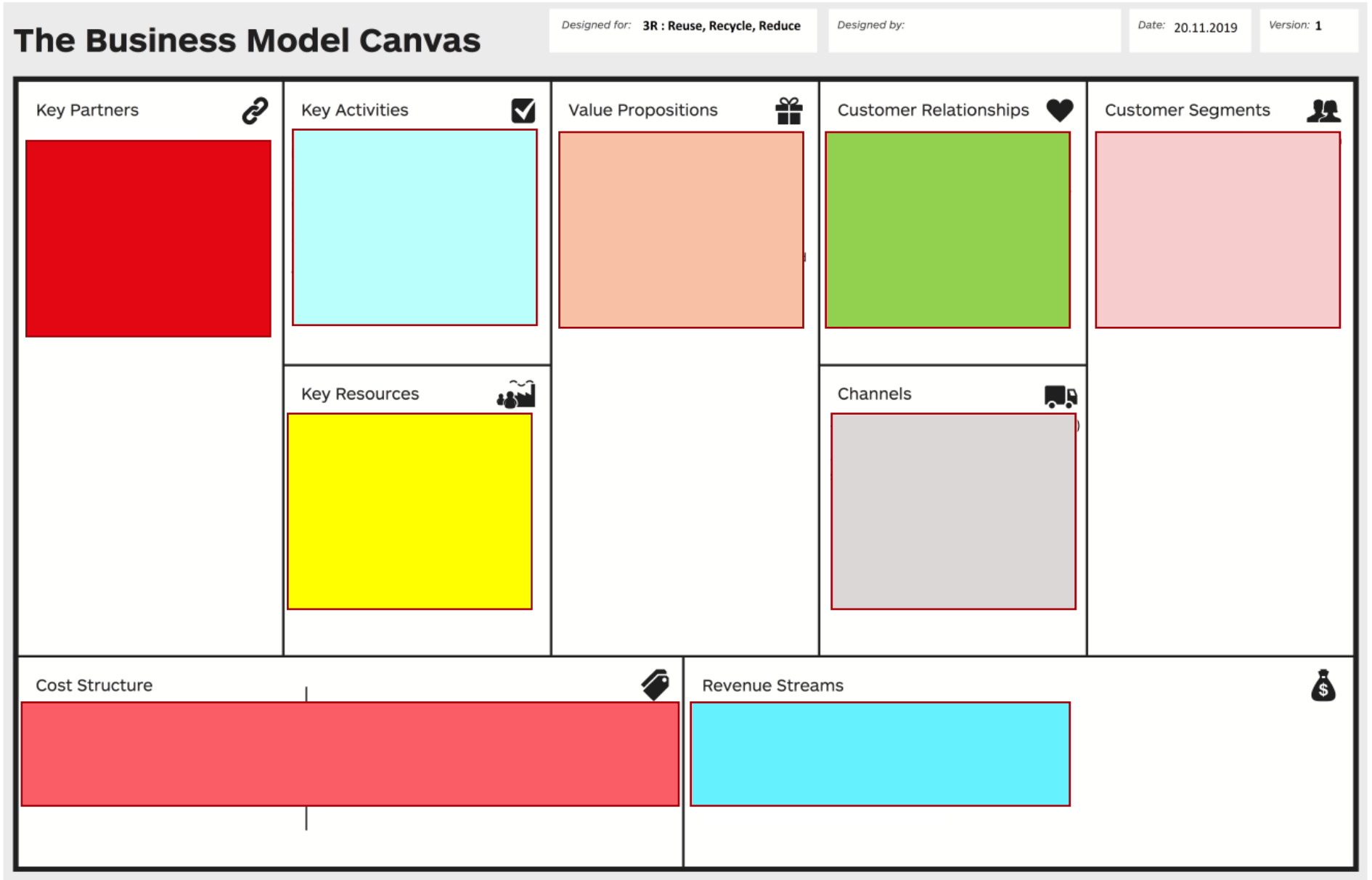


Figure 15: Extract of the ArcGIS Platform [7]

Source: CIVIL 424 (Fall 2019)

Business model canvas



Business model canvas

The Business Model Canvas

Designed for: **3R : Reuse, Recycle, Reduce** | Designed by: | Date: 20.11.2019 | Version: **1**

Key Partners

1. Demolition companies
2. Sand suppliers
3. Recycling companies
4. Construction companies
5. Authorities/Municipalities

Key Activities

1. Data management/treatment and interpretation
2. Collecting materials (demolition/sand/recycled)
3. Supply of the said materials
4. Label implementation

Key Resources

1. Construction waste
2. Sand
3. Data concerning collection of demolition concrete, wastes, sand
4. Optimisation software

Value Propositions

- Economy of sand
- Minimising the transport from production site to construction sites
- Less environmental impacts
- Label certification on the % of the recycled materials that has been used

Customer Relationships

- Individual support and expertise on the service and software
- Subcontractors for the supply of materials once the scheme and contract has been established

Channels

- Data service, software and report (@ ways)
- Physical transportation (roads, trains, ships, ...) --> subcontractor

Customer Segments

1. Biggest customers would be construction companies to which we will our services from the expertise to the supply for mutliples construction projects
2. We would create values from the revalorisation of materials we recycled or take from demolition sites

Cost Structure

Fixed Costs :
- Software management and development
- Data expertise and consulting
- Administration fees for the labelling

Variable costs :
- Materials collection (depends on the prices of the market)
- Transportation costs (distance and oil price)

Revenue Streams

- Expertise revenues (optimisation, labelling, consulting)
- Revalorisation on materials through recycling
- Subvention for environmental benefits and ecological label

The Business Model Canvas

Designed for:	Designed by:	Date:	Version:

Key Partners

Who are our Key Partners?
Who are our key suppliers?
Which Key Resources are we acquairing from partners?
Which Key Activities do partners perform?

MOTIVATIONS FOR PARTNERSHIPS
Optimization and economy
Reduction of risk and uncertainty
Acquisition of particular resources and activities

Key Activities

What Key Activities do our Value Propositions require?
Our Distribution Channels?
Customer Relationships?
Revenue streams?

CATEGORIES
Production
Problem Solving
Platform/Network

Key Resources

What Key Resources do our Value Propositions require?
Our Distribution Channels? Customer Relationships?
Revenue Streams?

TYPES OF RESOURCES
Physical
Intellectual (brand patents, copyrights, data)
Human
Financial

Value Propositions

What value do we deliver to the customer?
Which one of our customer's problems are we helping to solve?
What bundles of products and services are we offering to each Customer Segment?
Which customer needs are we satisfying?

CHARACTERISTICS
Newness
Performance
Customization
"Getting the Job Done"
Design
Brand/Status
Price
Cost Reduction
Risk Reduction
Accessibility
Convenience/Usability

Customer Relationships

What type of relationship does each of our Customer Segments expect us to establish and maintain with them?
Which ones have we established?
How are they integrated with the rest of our business model?
How costly are they?

EXAMPLES
Personal assistance
Dedicated Personal Assistance
Self-Service
Automated Services
Communities
Co-creation

Channels

Through which Channels do our Customer Segments want to be reached?
How are we reaching them now?
How are our Channels integrated?
Which ones work best?
Which ones are most cost-efficient?
How are we integrating them with customer routines?

CHANNEL PHASES
1. *Awareness*
   How do we raise awareness about our company's products and services?
2. *Evaluation*
   How do we help customers evaluate our organization's Value Proposition?
3. *Purchase*
   How do we allow customers to purchase specific products and services?
4. *Delivery*
   How do we deliver a Value Proposition to customers?
5. *After sales*
   How do we provide post-purchase customer support?

Customer Segments

For whom are we creating value?
Who are our most important customers?

Mass Market
Niche Market
Segmented
Diversified
Multi-sided Platform

Cost Structure

What are the most important costs inherent in our business model?
Which Key Resources are most expensive?
Which Key Activities are most expensive?

IS YOUR BUSINESS MORE
Cost Driven (leanest cost structure, low price value proposition, maximum automation, extensive outsourcing)
Value Driven (focused on value creation, premium value proposition)

SAMPLE CHARACTERISTICS
Fixed Costs (salaries, rents, utilities)
Variable costs
Economies of scale
Economies of scope

Revenue Streams

For what value are our customers really willing to pay?
For what do they currently pay?
How are they currently paying?
How would they prefer to pay?
How much does each Revenue Stream contribute to overall revenues?

TYPES
Asset sale
Usage fee
Subscription Fees
Lending/Renting/Leasing
Licensing
Brokerage fees
Advertising

FIXED PRICING
List Price
Product feature dependent
Customer segment dependent
Volume dependent

DYNAMIC PRICING
Negotiation (bargaining)
Yield Management
Real-time-Market

Strategyzer
strategyzer.com

What the result of the BMC might look like?

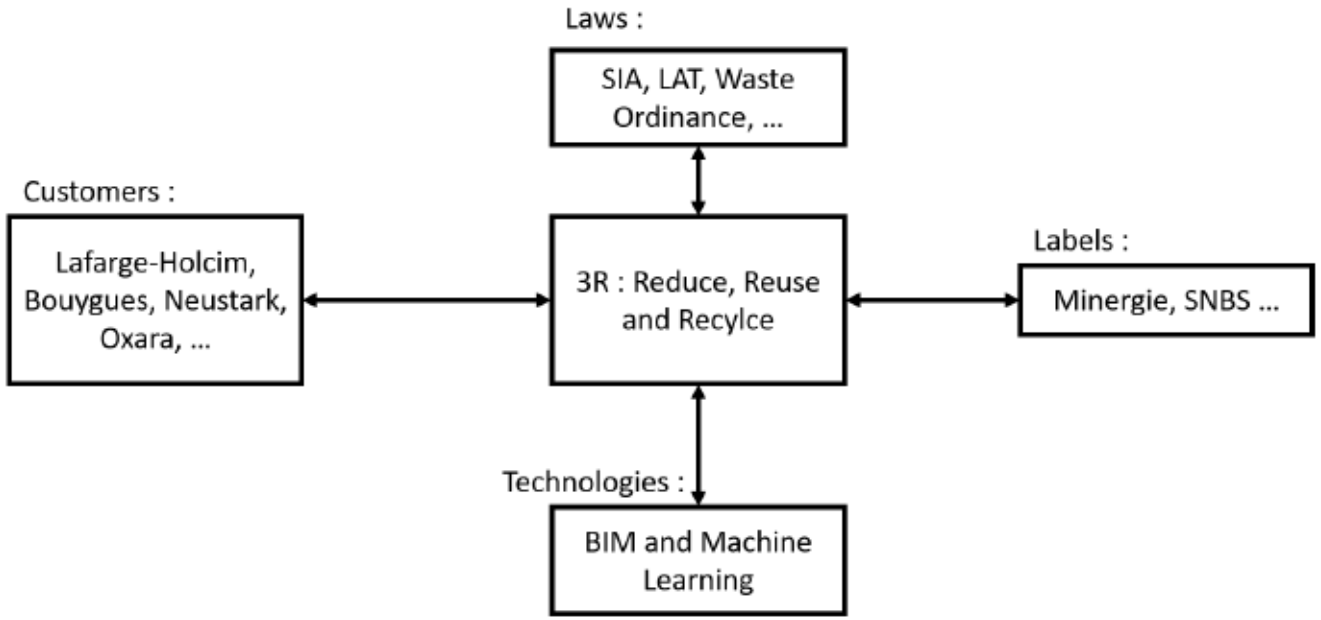


Figure 9: Links with others sectors for 3R : Reduce, Reuse and Recycle

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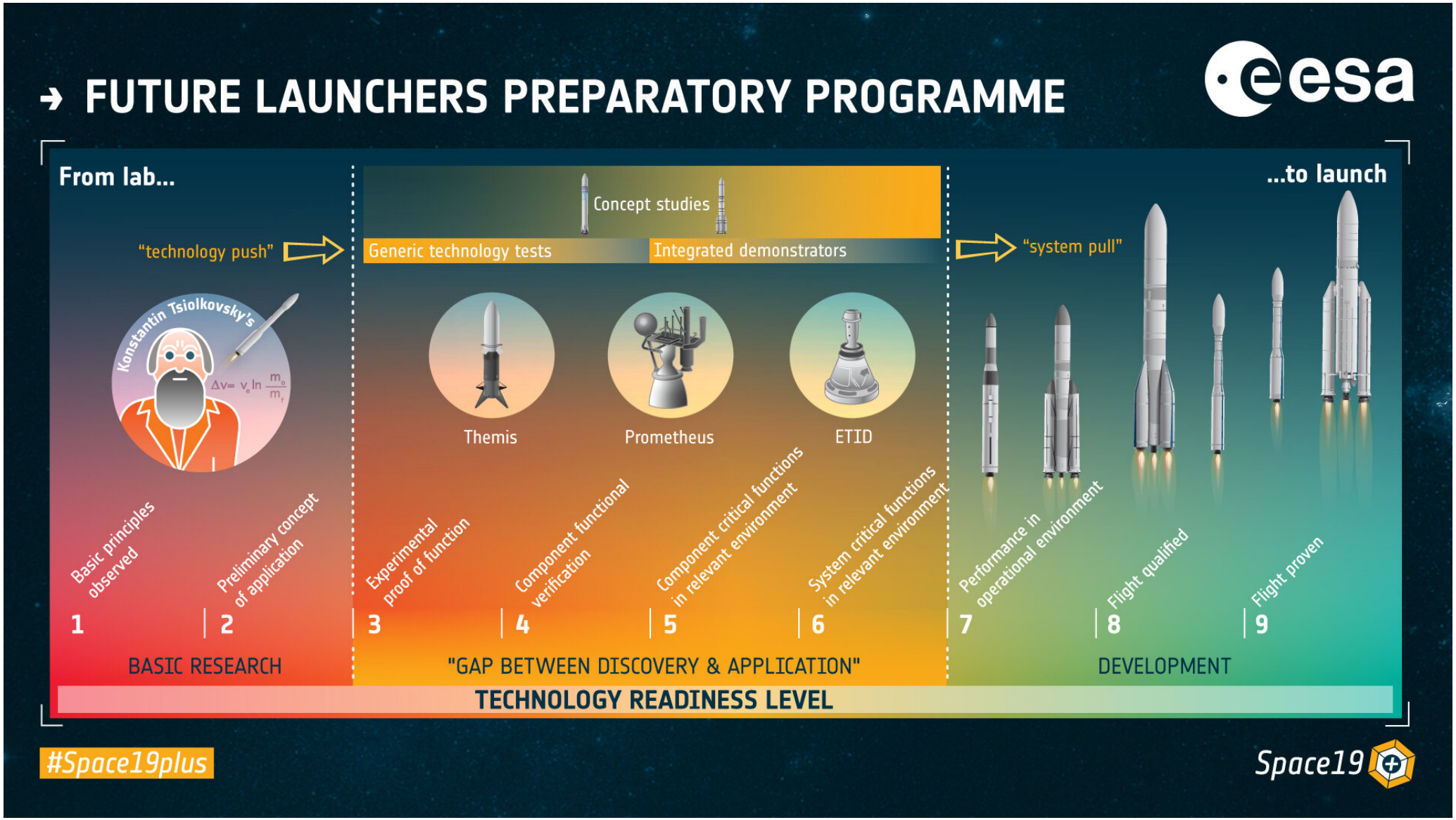
Technology readiness level



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Technology Readiness Level

Technology readiness levels (**TRLs**) estimate the **maturity** of technologies. The European Commission advised EU-funded research and innovation projects to adopt the scale in 2010.

PoC

- TRL 1 – basic principles observed
- TRL 2 – technology **P**roof **o**f **C**oncept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab

Make or break

- TRL 5 – technology validated **in relevant environment**
- TRL 6 – technology demonstrated **in relevant environment**
- TRL 7 – system prototype demonstration in operational environment

Likely failure in integration

- TRL 8 – system **complete and qualified**
- TRL 9 – actual system proven in operational environment (**competitive manufacturing**)

Technology Readiness Level

Dr. Dimitrios Terzis

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PoC

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Evaluate the TRL of your chosen vertical!

Directeur-adjoint chez Grisoni-Zaugg
3d •

1er BFUP pour le SPC Fribourg, ca c'est fait !!!

See translation

94 · 7 Comments

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Evaluate the TRL of your chosen vertical!

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Congratulations to MOBBOT, our portfolio company, for establishing a new collaboration with Matériaux Sabag, joining forces to produce 3D printed elements using sprayed concrete.
Thanks to MOBBOT's additive manufacturing solution, Matériaux Sabag will be able to expand its product portfolio, especially in the field of infrastructures.
"We will be able to respond to time-sensitive requests and offer our customers greater flexibility, tailored to the requirements of the construction sites," says Cédric Theubet, Operations Manager at Matériaux Sabag. This solution will be presented to partners and customers in the coming days and will be available by the end of September 2020.

More info in the press release: https://lnkd.in/di-NNzB

#3Dprinting #startups #construction Agnès Petit Markowski

Technology Readiness Level & Time

When something is ready to launch...

Dr. Dimitrios Terzis

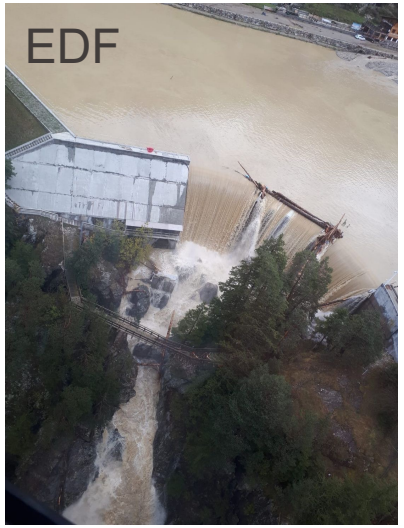
Technology Readiness Level & Time

When something is ready to launch… but stays too long on the launch pad

Value creation

Value creation and perception

The world without us (business as usual – BAU)



The world with us:

A key target is to realize the full development potential of projects (value creation)

costs, time, safety, longevity, side-effects, upgrade

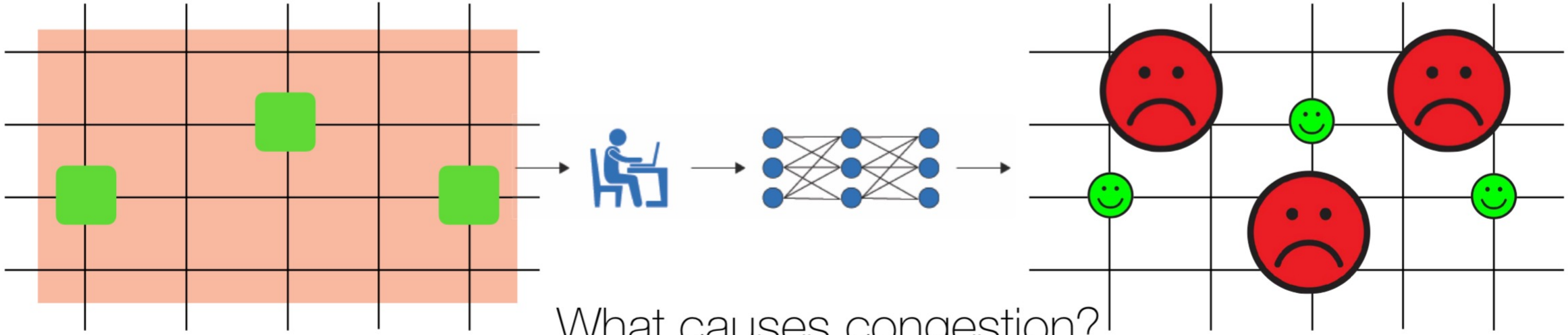
(client, contractor, employee/contractor, user, public, current/future owner)

Value creation and perception

The Problem

In the U.S. alone congestion cost **$305** billion in 2017

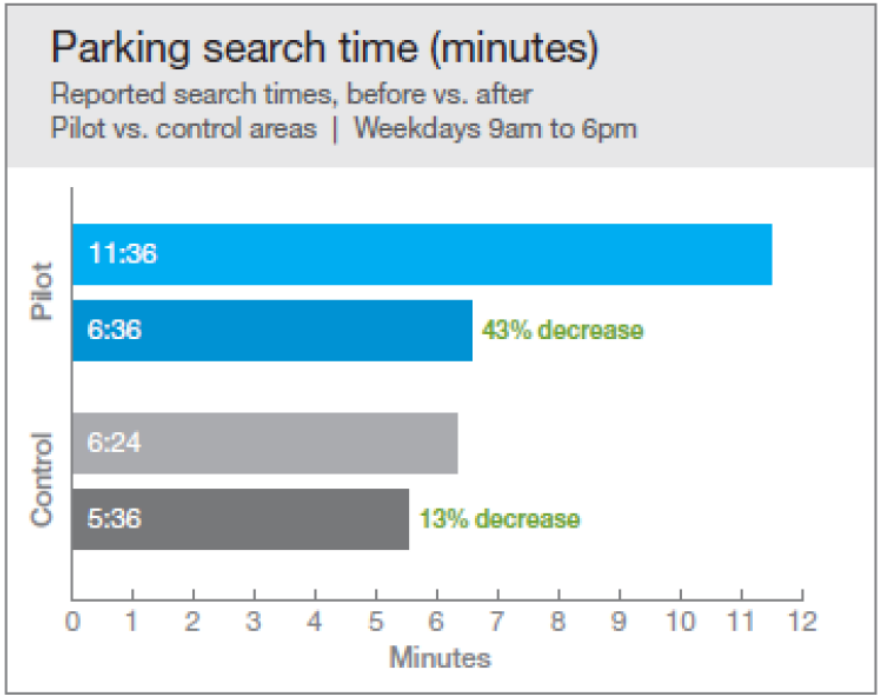
Before



After

What causes congestion?

Value creation and perception



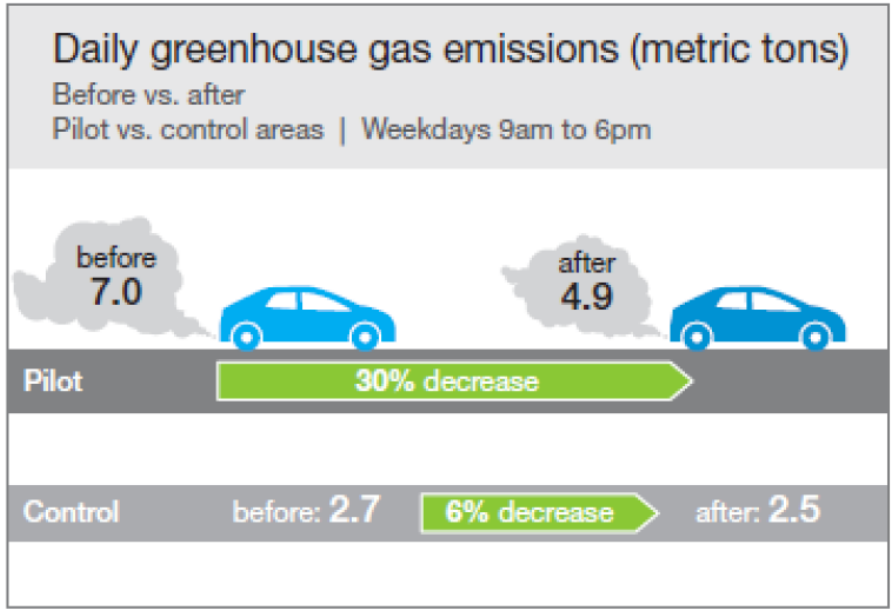
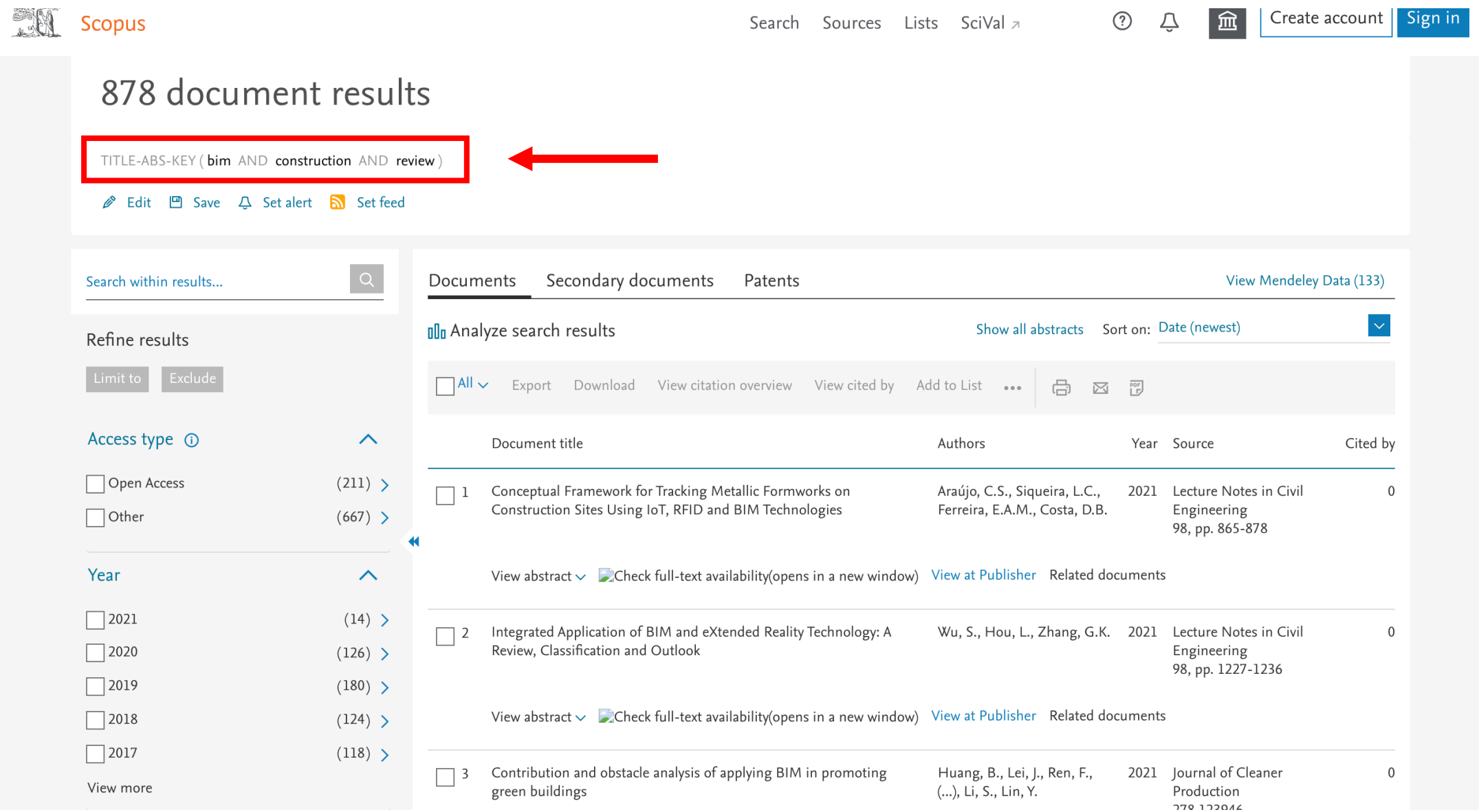
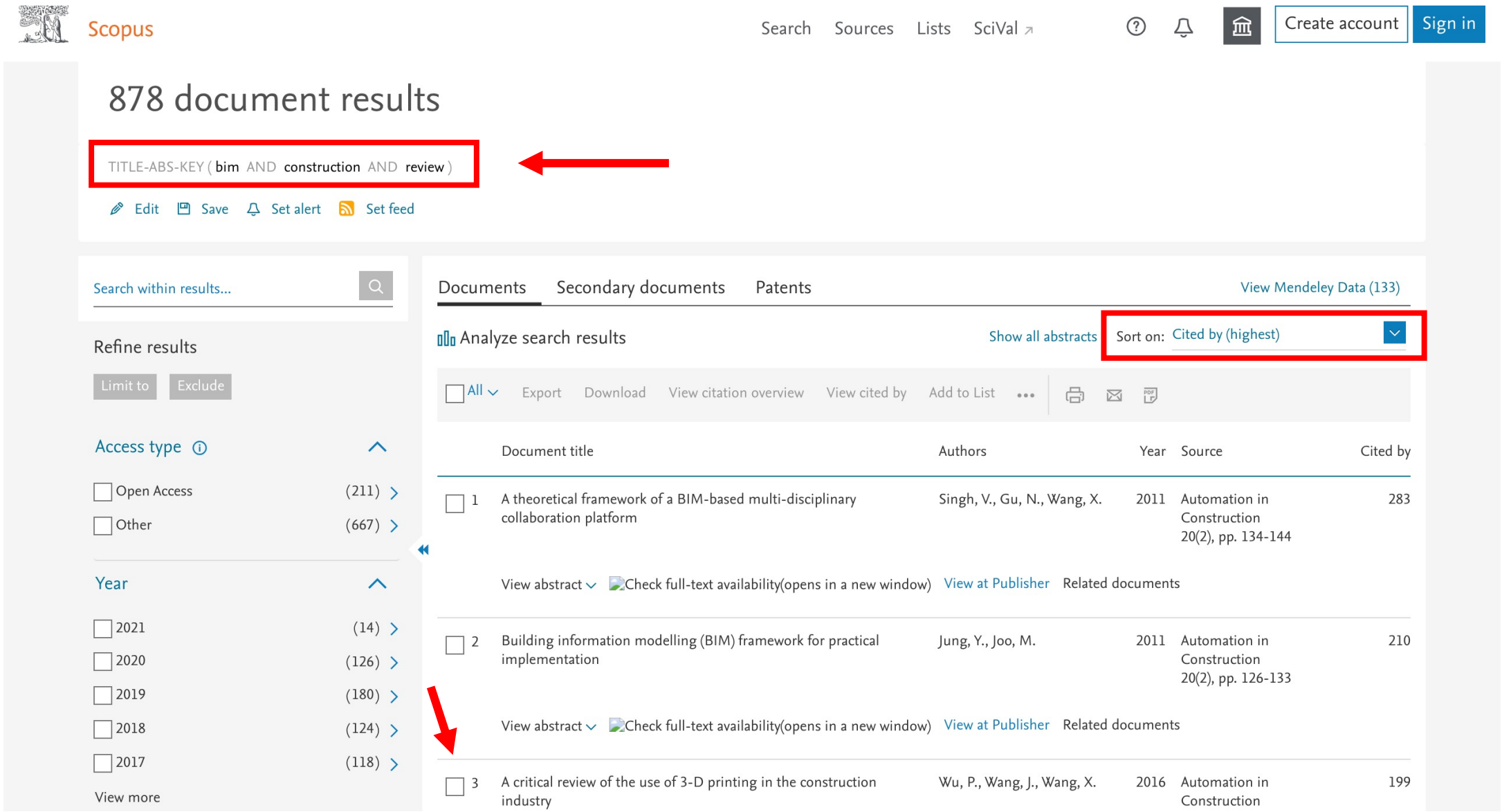


Figure 3 – Effect of the SFpark pilot project, a) the impact on the search time, b) the impact on the greenhouse gas emissions. [9]

Tips for your literature review: BIM example



Tips for your literature review: BIM example



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Tips for your literature review: BIM example

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Automation in Construction
Volume 68, August 2016, Pages 21-31

A critical review of the use of 3-D printing in the construction industry (Review)

Wu, P.[a], Wang, J.[b], Wang, X.[b]

[a]Department of Construction Management, Curtin University, Perth, Australia
[b]Australasian Joint Research Centre for Building and Information Modelling, Curtin University, Perth, Australia

Abstract

View references (78)

3-D printing, which is an automated production process with layer-by-layer control, has been gaining rapid development in recent years. The technology has been adopted in the manufacturing industry for decades and has recently been introduced in the construction industry to print houses and villas. The technology can bring significant benefits to the construction industry in terms of increased customization, reduced construction time, reduced manpower, and construction cost. A few isolated products and projects have been preliminarily tested using the 3-D printing technology. However, it should be noted that such tests and developments on the use of 3-D printing in the construction industry are very fragmented at the time of the study. It is therefore necessary for the building and construction industry to understand the technology, its historical applications and challenges for better utilization in the future. A systematic review shows that 3-D printing technology, after years of evolution, can be used to print large-scale architectural models and buildings. However, the potential of the technology is limited by the lack of large-scale implementation, the development of building information modeling, the requirements of mass customization, and the life cycle cost of the printed projects. It is therefore expected that future studies should be conducted on these areas to consolidate the stability and expand the applicability of 3-D printing in the construction industry.

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PlumX Metrics
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Automation of the construction process by using a hinged robot with interchangeable nozzles
Grigoryan, E. , Babanina, A. , Kulakov, K. *(2021) Advances in Intelligent Systems and Computing*

BIM-enabled computerized design and digital fabrication of industrialized buildings: A case study

What do these papers touch?
- Hardware
- Case study

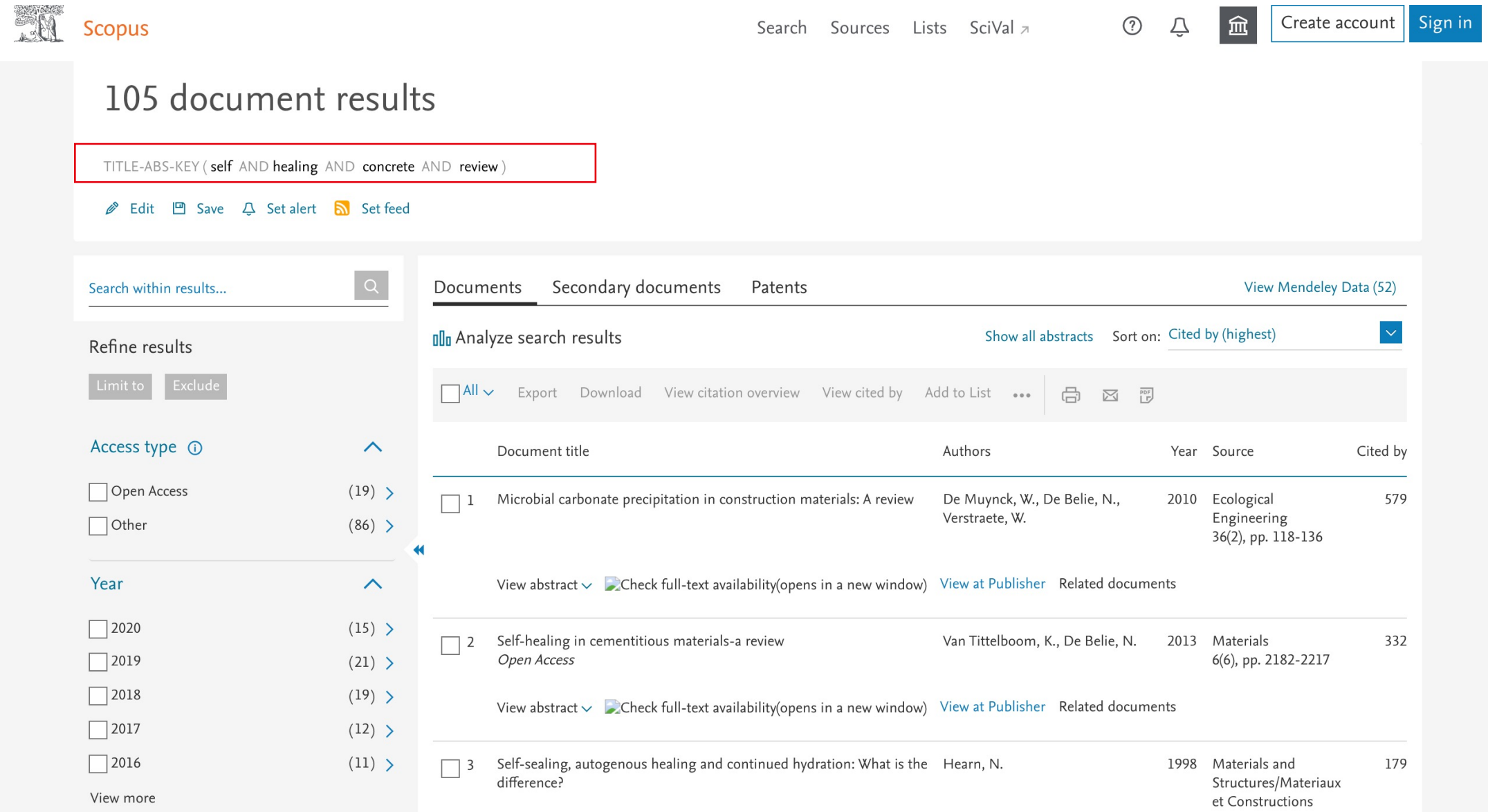
Tips for your literature review: BIM example

The average value of construction disputes in the UK fell by a massive 47% last year, the value of disputes averaged just $17.9m (£14.13m) in 2018; well below the global average of $33m (£26.04m) and marking a significant decrease over the last six years. According to the report, the UK also remained the jurisdiction with the shortest average length of time to solve a dispute – 12.8 months.

Non academic references:
https://www.arcadis.com/en/united-kingdom/our-perspectives/2019/june/global-construction-disputes-report-2019/

However, our results show the UK to be a world leader in effective avoidance and mitigation strategies, and as we continue to transition towards greater use of digital technologies like BIM and 4-, 5- or 6D modelling, we are likely to see an improvement in risk allocation much earlier on in the process. This could help all parties to collaboratively resolve any difficulties before cost and time pressures start to escalate.

Tips for your literature review: self-healing



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Tips for your literature review: self-healing

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Advances in Civil Engineering Materials
Volume 8, Issue 3, 9 September 2019

Smart self-healing and self-sensing cementitious composites-recent developments, challenges, and prospects (Article)

Das, A.K.[a], Mishra, D.K.[b], Yu, J.[a], Leung, C.K.Y.[a]

[a]Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong
[b]KMBB College of Engineering and Technology, Biju Patnaik University of Technology (BPUT), Khordha, 752056, India

Abstract

View references (164)

The use of smart cementitious materials is becoming increasingly critical for the enhanced serviceability of structures. The addition of carbon fibers, carbon nanotubes, and various nano-powders such as nano-silica, carbon black, and graphite giving cementitious materials electrical properties that can be used for self-sensing has been known for almost two decades. Many sensing principles and techniques using smart materials have been successfully developed and applied mostly in laboratory testing over last few decades. The strong capacity of Fiber-Reinforced Cementitious Composites for autogenous healing in addition to crack control (especially in the case of Strain-Hardening Cementitious Composites) has been reported by many researchers. Similarly, the applications of different mineral and bio-additive materials to achieve the self-healing of cracks have been noted with great interest. Design for serviceability based on the durability of the materials used in concrete structures is often neglected. With durability performance testing becoming more sophisticated, detailed service life design is being demanded in the most important infrastructure projects. The present review is focused on identifying field applications and highlighting the Performance-Driven Design Approach for tailoring material solutions for the problems likely to be faced by civil infrastructures in the future. A real-life case study is presented to illustrate the minimal cost implications of adopting the latest smart material for an eco-friendly, durable, reliable, and resilient infrastructure. Identifying critical challenges faced by the industry and developing solutions for the same is going to help bridge the current gaps between research and adoption.

SciVal Topic Prominence

Topic: Strain Hardening | Reinforced Concrete | Pullout Test

Cited by 8 documents

Qualitative assessment of interfacial bonding in 3D printing concrete exposed to frost attack
Assaad, J.J. , Hamzeh, F. , Hamad, B.
(2020) Case Studies in Construction Materials

ICD: A methodology for real time onset detection of overlapped acoustic emission waves
Das, A.K. , Leung, C.K.Y.
(2020) Automation in Construction

Pore and phase identification through nanoindentation mapping and micro-computed tomography in nanoenhanced cement
Konstantopoulos, G. , Koumoulos, E. ,

What do these papers touch?
- Risks
- Monitoring of risks, lets have a closer look

Dr. Dimitrios Terzis

Tips for your literature review: self-healing

Automation in Construction
Volume 119, November 2020, Article number 103341

ICD: A methodology for real time onset detection of overlapped acoustic emission waves (Article)

Das, A.K., Leung, C.K.Y.

Hong Kong University of Science and Technology (HKUST), Clear Water Bay Road, Hong Kong

Abstract

View references (40)

Accurate time of arrival (TOA) detection is essential for successful wave and vibration-based structural health monitoring (SHM) system including Acoustic Emission (AE). AE is the foremost among passive wave-based monitoring systems. During high burst rate results, AE waves could overlap. Overlapping of AE waves leads to overlap in both time and frequency. As a result, the TOA information is lost in the coda of the previous wave and cannot be (reliably) detected by conventional techniques. To this end, ICD is introduced. ICD involves 3 cascaded systems a) (Overlapping) Identification b) (Overlap) Cleaning c) (Arrival) Detection. A novel 3D Fingerprint is meticulously designed to autogenously and injectively identify the overlapping waves. Positive identification activates the cleaning system which eradicates the influence of the Intersecting Wave using newly proposed adaptive spectral subtraction (ASpS). Then, TOA for the Intersected Wave was identified. The approaches were verified in controlled as well as source localization tests. The results from controlled study validate robustness in low IRR values for a wide range of waveform parameters. Finally, source localization results from laboratory testing confidently display the scientific applicability of the proposed system. This system could enhance detectability, reliability, and accuracy of a conventional system. © 2020 Elsevier B.V.

Tips for your literature review: self-healing

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Construction and Building Materials
Volume 107, 15 March 2016, Pages 125-137

Comparison of different approaches for self-healing concrete in a large-scale lab test (Article)

Van Tittelboom, K.[a], Wang, J.[a,b,†], Araújo, M.[a,c,†], Snoeck, D.[a], Gruyaert, E.[a], Debbaut, B.[a], Derluyn, H.[d], Cnudde, V.[d], Tsangouri, E.[e,†], Van Hemelrijck, D.[e], De Belie, N.[a]

[a]Magnel Laboratory for Concrete Research, Department of Structural Engineering, Faculty of Structural Engineering and Architecture, Ghent University, Technologiepark Zwijnaarde 904, Ghent, B-9052, Belgium
[b]Laboratory of Microbial Ecology and Technology, Department of Biochemical and Microbial Technology, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, Ghent, B-9000, Belgium
[c]Polymer Chemistry and Biomaterials Group, Department of Organic and Macromolecular Chemistry, Faculty of Sciences, Ghent University, Campus Sterre Building S4, Krijgslaan 281, Ghent, B-9000, Belgium

View additional affiliations

Abstract

View references (22)

After several years of research in the Magnel Laboratory for Concrete Research (Belgium) to obtain concrete with self-healing properties, two of the most promising mechanisms were tested on a larger scale. One mechanism is based upon the encapsulation of polyurethane which is embedded in the matrix. Self-repair is obtained when crack creation causes capsule breakage, release and subsequent hardening of the polyurethane inside the crack. The second approach relies upon the addition of superabsorbent polymers (SAPs) to the concrete. These SAPs take up water entering via the crack, swell and block the crack. In addition, when they release their water content later on, they induce continued hydration and calcium carbonate precipitation. Real-scale concrete beams (150 mm × 250 mm × 3000 mm), with and without self-healing properties, were made and the self-healing efficiency was evaluated after crack creation by means of four-point bending. Based on the measured crack width reduction over time, it was shown that improved autogenous crack healing was obtained when superabsorbent polymers were added to the mixture. From the acoustic emission analysis, the proof of glass capsule breakage upon crack formation was obtained. X-ray tomography, fluorescent light microscopy and thin section analysis demonstrated that cracks were indeed partially filled with hydration products, calcium carbonate crystals and/or polyurethane which leached from the broken embedded capsules. Although it would be expected from both findings that this would result in a decrease of water ingress into the healed cracks, this could not be proven within this study.

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PlumX Metrics
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Cited by 70 documents

Self-healing capacity of fiber-reinforced calcium phosphate cements
Boehm, A.V. , Meininger, S. , Gbureck, U.
(2020) Scientific Reports

Advanced smart concrete - A review of current progress, benefits and challenges
Makul, N.
(2020) Journal of Cleaner Production

Evaluation of corrosion inhibition and self healing capabilities of nanoclay and tung oil microencapsulated epoxy coatings on rebars in concrete
Sharma, N. , Sharma, S. , Sharma, S.K.
(2020) Construction and Building Materials

View all 70 citing documents

What do these papers touch?
- Interactions with reinforcement
- Risks

Thank you!

Dr. Dimitrios Terzis

14/10/2025

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