Subject/Title

Comparative **digital design** strategies for structural systems of mid-rise building:

… in the view of building as:

materials stock from expert environmental impact assessment.

- **Maryam Jafari**

Mid-rise building : 50 -200 m height

Considered structural systems are:

- shear wall
- Frame system (braced frame, rigid frame)
- outrigger and belt
- Tube system (framed tube, braced tube, tube in tube)
- diagrid, space truss
- exoskeleton
- mushroom-slabs systems

Considered materials are:

- Timber: [massive, GL, CLT]
- Concrete: [cast-in-situ, prefab, printed, formwork printed, HRFRC]
- steel
- combined materials of various grades / strength classes.

Main objective

meeting the need for **efficiency** and comprehensive **evaluation** in the design of mid-rise buildings

Special objective

Evaluate relative **performances** through parametrized systems

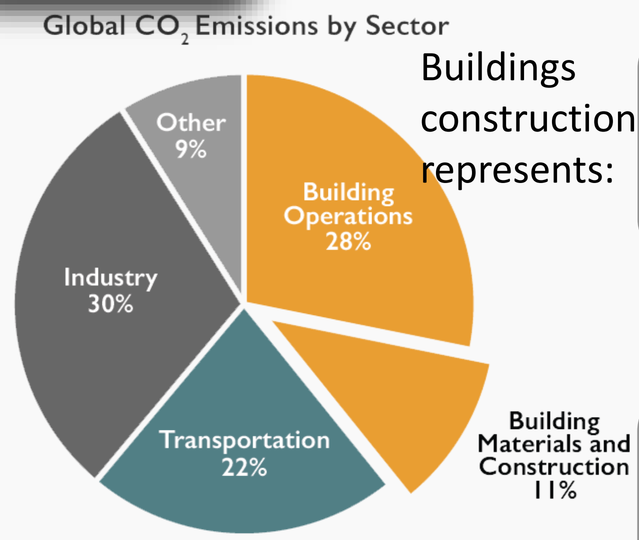
Examining potential for **digital manufacturing**

provide **graphs** or **nomograms** of multi-criteria optimal strategies

potential **reuse** of structural components

Building as material stock

Disassemble building



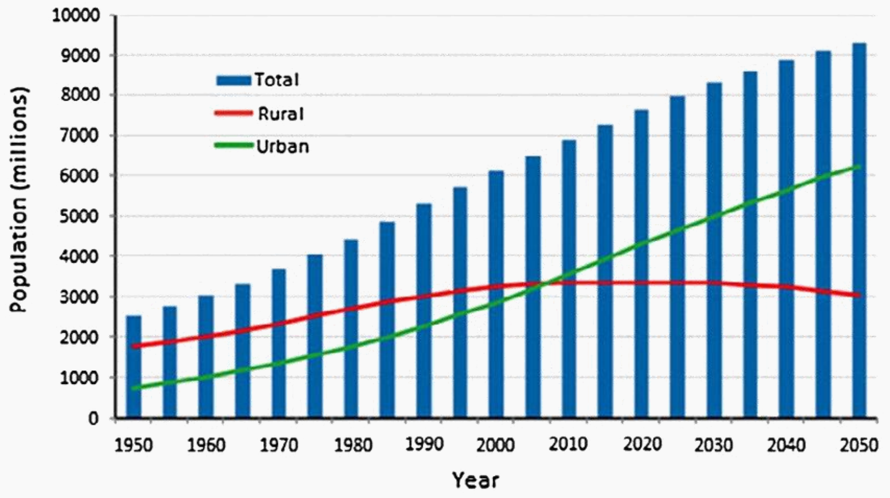
Buildings construction represents:

- **11%** of CO2 emissions (energy sector)
- **6%** of energy consumption

+ Population growth

9.7 billion in 2050

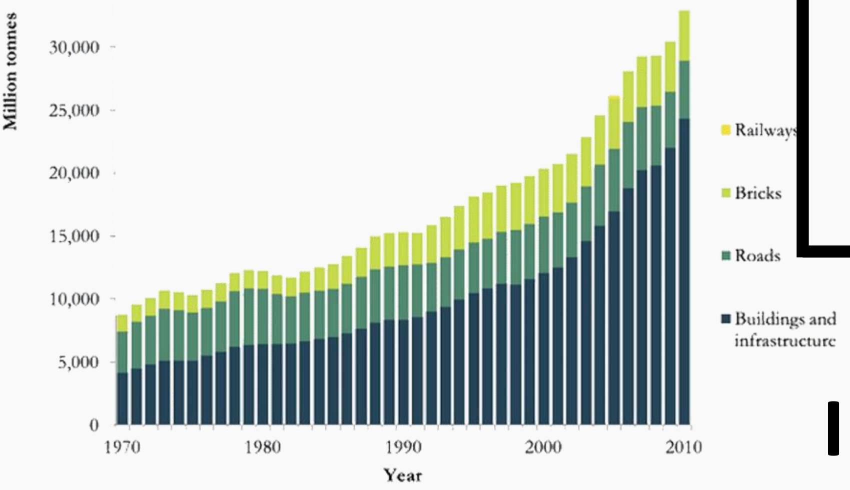
Urbanization rate: 66% in 2050



40% of extracted resources

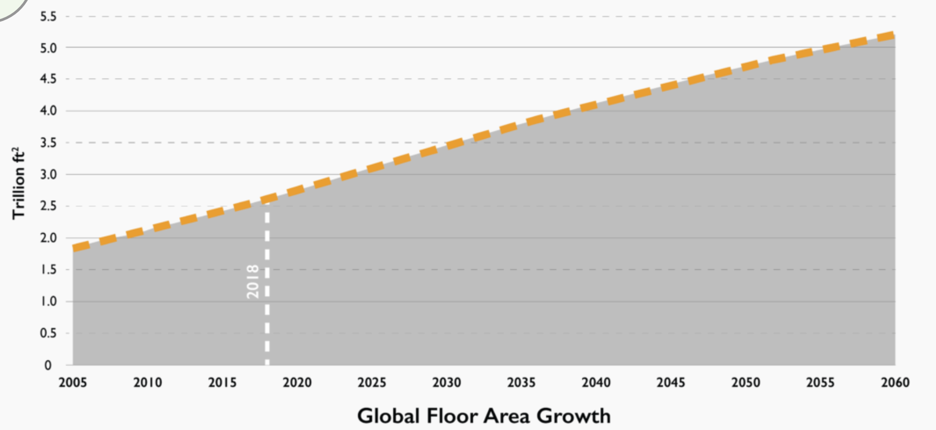
Global **building stock**:

double by 2060

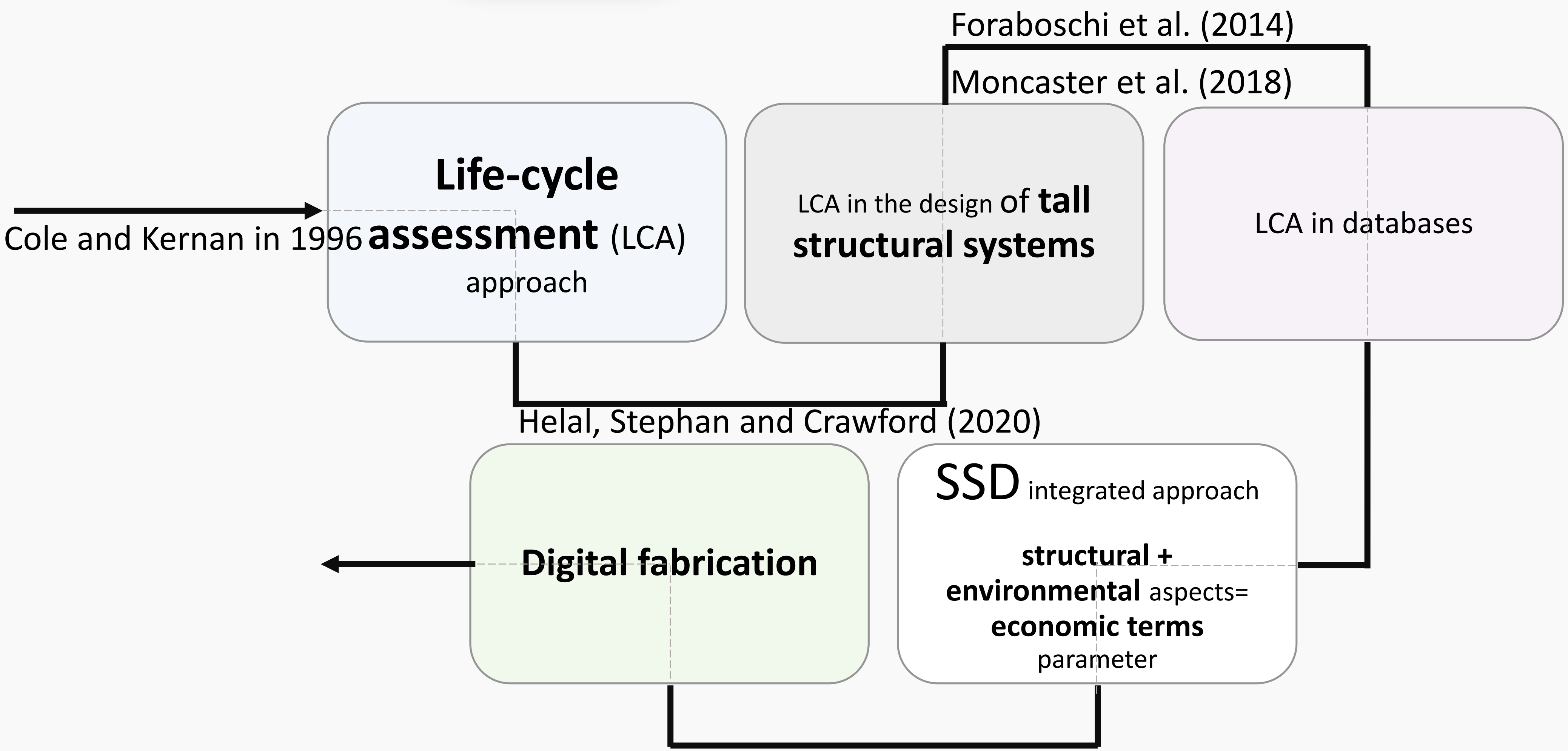


59.57–66.73% of building's total embodied energy

structure accounts:



Impact < > Needs


Foraboschi et al. (2014)
Moncaster et al. (2018)
Cole and Kernan in 1996
Life-cycle assessment (LCA) approach
LCA in the design of tall structural systems
LCA in databases
Helal, Stephan and Crawford (2020)
Digital fabrication
SSD integrated approach
structural + environmental aspects= economic terms parameter

Research phases

- **Literature review**

Expected Result

State of the art for structural design, structural efficiency, economy, and environmental behavior in middle-rise buildings

- **modelling strategies and assessment approaches**

Expected Result

Selecting structural assessment and LCA approach & parameters. Extracting useful data from the associated environmental database.

- **Parametric and interactive combined simulations**

Expected Result

Assembling **parametric models** and implementing simulations.
Providing **charts** demonstrating most efficient and greener strategies.

- **sorting structural strategies**

Expected Result

Questioning the positive influence of digital fabrication on **environmental indicators**.
Testing the transfer of selected parametric models to numerical definition for CNC.

- **Scientific reporting**

WP0

- 0. Constructive scenarios (input)

WP1:

- 1.1. WP.1. Literature input.

- **WP2:**
  - 2.1. Methods for the structural assessment
  - 2.2. Selecting LCA relevant approach & parameters
  - 2.3. Checking relevant structural "optimization" /definition approach

- **WP3:**
  - 3.1. Parametric models
  - 3.2. Parametric combined simulation
  - 3-3. Charts for optimal strategies

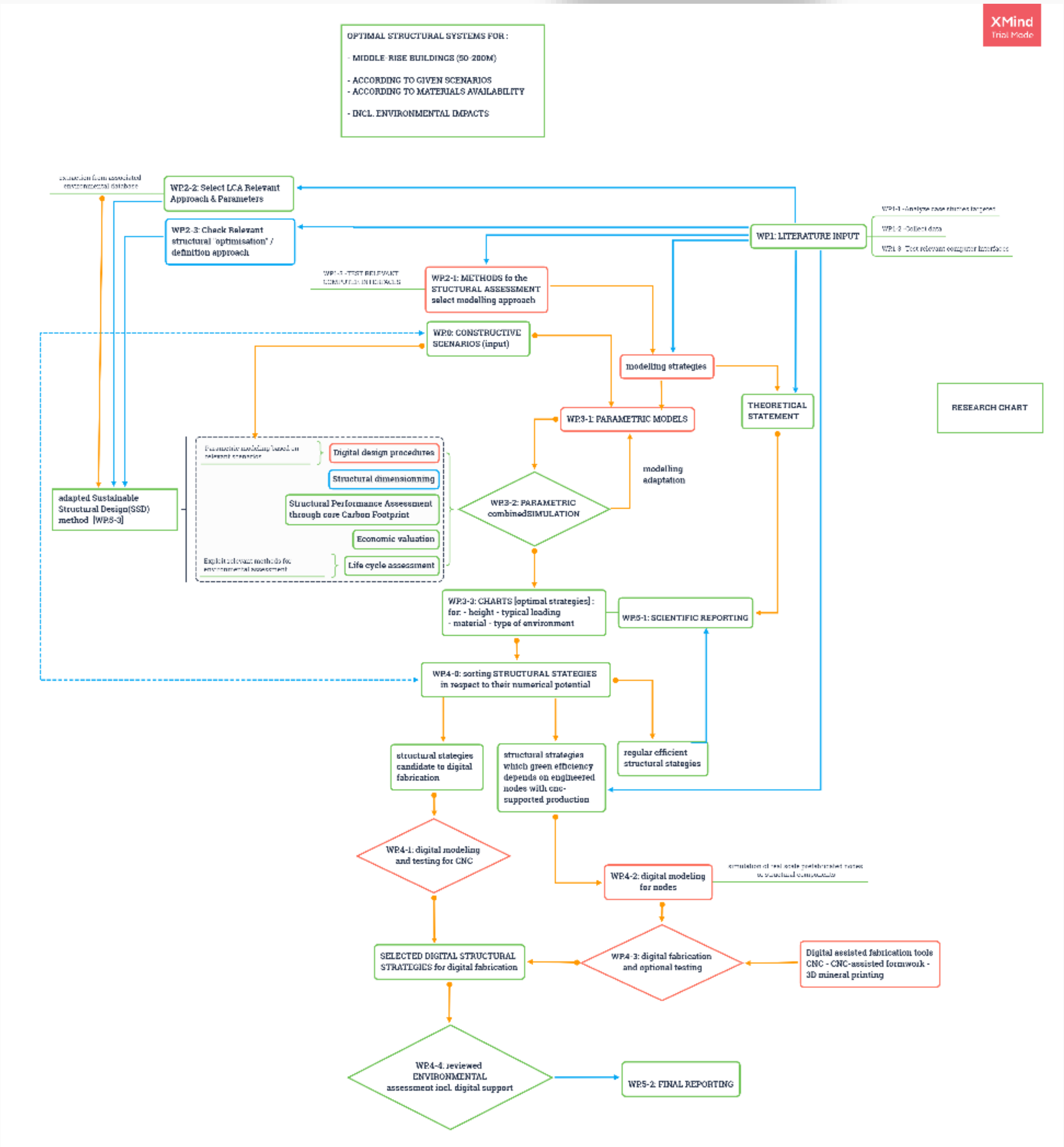
- **WP4:**

- 4-0. structural strategies with respect to the numerical potential
- Digital modelling and testing for CNC
- 4.2. real scale prefabricated nodes/structural components
- 4-3. Digital fabrication and optional testing

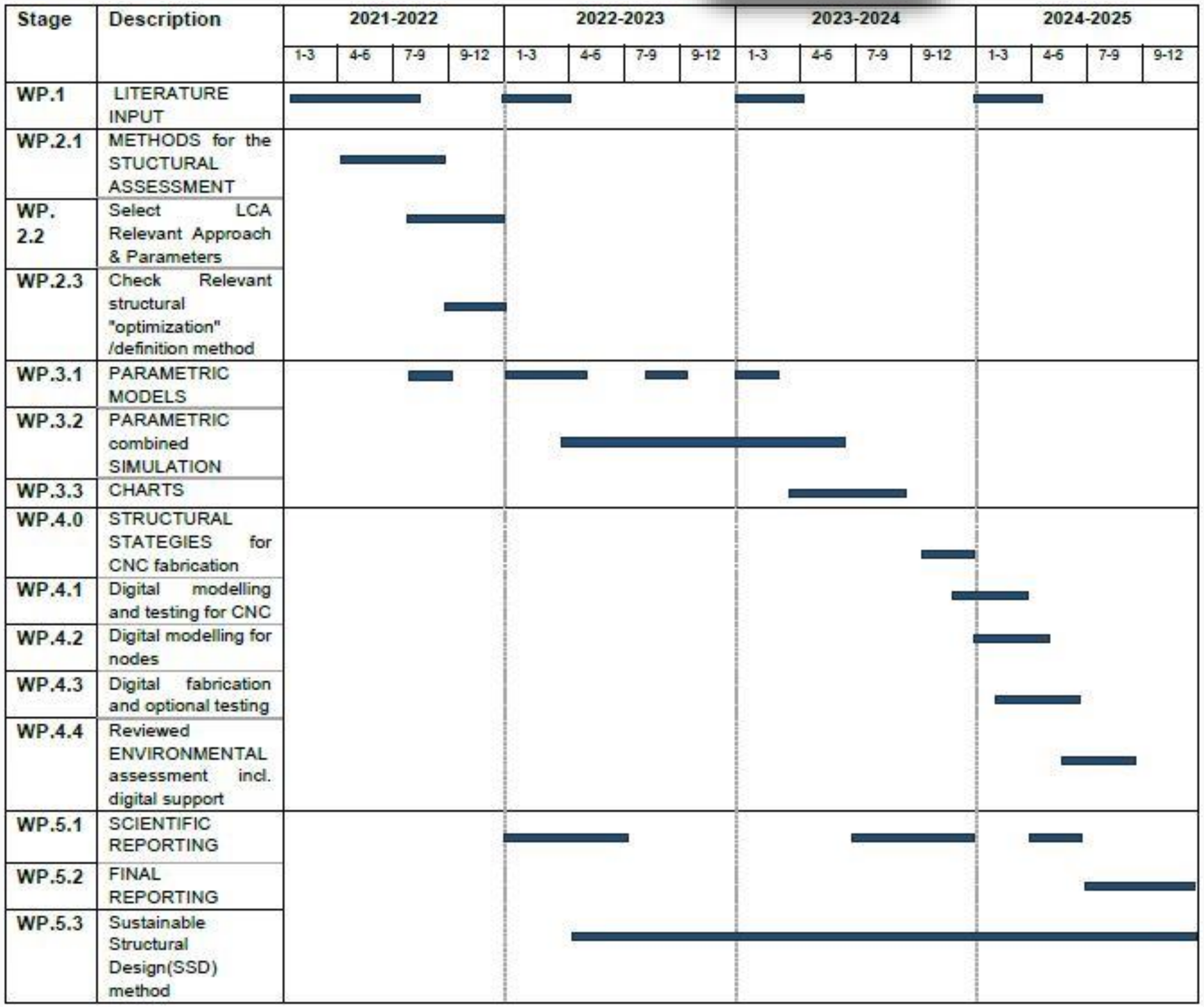
- **WP5:**

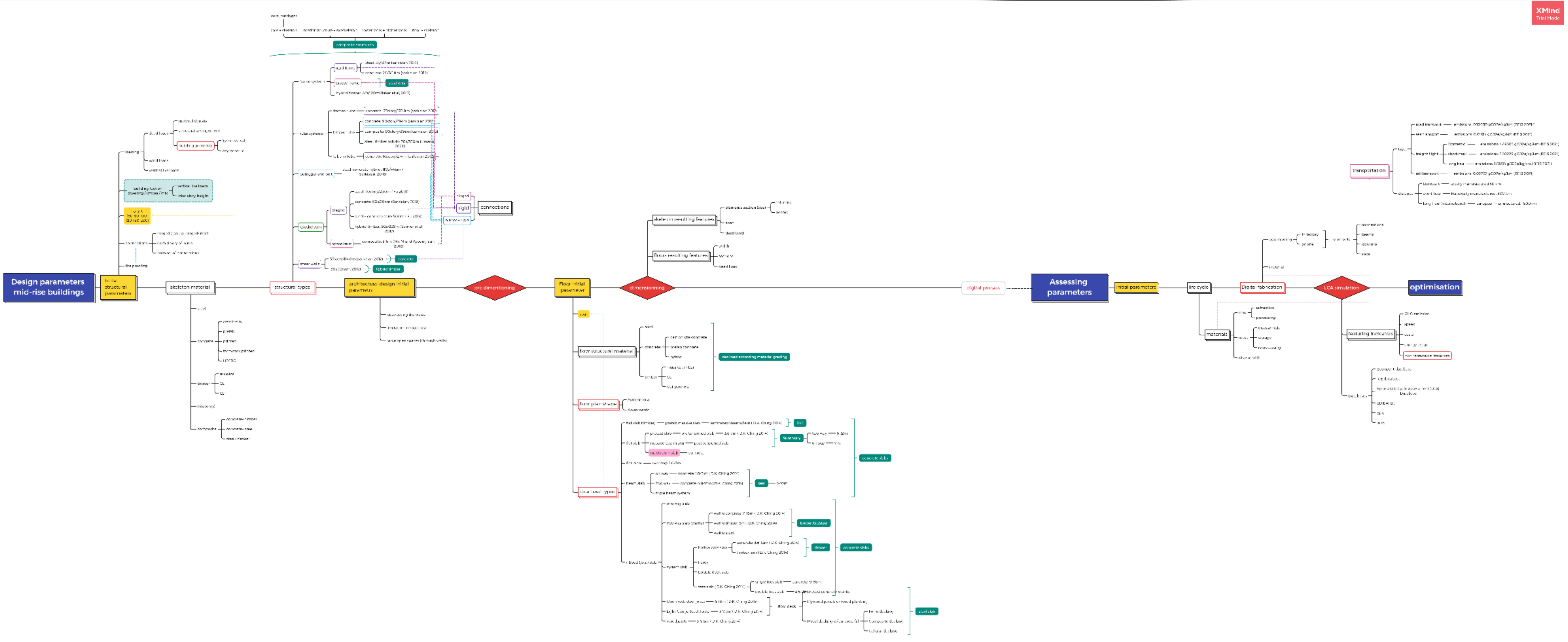
- 5 Scientific reporting
- 5.1. Intermediate results on green structural strategies.
- 5.2. Final reporting
- 5.3. Possible benefits of adapting the (SSD) method

Research chart



Work plan


Stage
Description
2021-2022
2022-2023
2023-2024
2024-2025
1-3
4-6
7-9
9-12
WP.1 LITERATURE INPUT
WP.2.1 METHODS for the STUCTURAL ASSESSMENT
WP. 2.2 Select LCA Relevant Approach & Parameters
WP.2.3 Check Relevant structural "optimization" /definition method
WP.3.1 PARAMETRIC MODELS
WP.3.2 PARAMETRIC combined SIMULATION
WP.3.3 CHARTS
WP.4.0 STRUCTURAL STATEGIES for CNC fabrication
WP.4.1 Digital modelling and testing for CNC
WP.4.2 Digital modelling for nodes
WP.4.3 Digital fabrication and optional testing
WP.4.4 Reviewed ENVIRONMENTAL assessment incl. digital support
WP.5.1 SCIENTIFIC REPORTING
WP.5.2 FINAL REPORTING
WP.5.3 Sustainable Structural Design(SSD) method


Design parameters mid-rise buildings
Initial structural parameters
skeleton material
structure types
architecture design initial parameters
pre dimentioning
Floor initial parameter
dimentionning
connections
floor structural material
floor plan shape
digital process
Assessing parameters
initial parameters
life cycle
materials
Digital fabrication
LCA simulation
featuring indicators
optimisation
transportation

LCA database

- Ecoinvent database
- ICE database
- Sphera Life Cycle Assessment (LCA) Database
- EDIBATEC
- Epic: hybrid LCA assessment
- Inies

Sustainability certificates

- LEED: American and Canadian sustainability certification
- BREEAM: British sustainability certificate
- CASBEE: Asian sustainability certificate
- DGNB: German sustainability certificate
- Green Star: Australian Sustainability Certificate
- HQE: French sustainability certificate
- LENOZ: Luxembourg sustainability certificate
- Environmental label wood from here
- BNB: Evaluation system for sustainable building for federal buildings

Standards

- EN 15804:2012+A1:2013(MAIN)
- BS EN 15804:2012+A2:2019
- ISO 14040:2006/AMD 1:2020
- RICS professional standards and guidance
- LPCB standards and certification

LCA deceleration

- EPD
- FDES

Software for LCA

Totem, SimaPro, GaBi, Air.e LCA, OpenLCA, Umberto, One Click LCA, Trayak, eBalance, EIME, Ecodesign Studio, Carbmee, TEAM 5.2, iPoint Compliance Agent LCA Module, LifeCycle Tracker, Aveny LCA 2, eToolLCD, Granta Design Solutions, EcodEx, EarthSmart, Air.e HdC, ECODESIGN+, Instant LCA Packaging, PackageSmart, Bilan Produit, CCaLC, Eco-Bat, Pleiades ACV, CO2Print Modeler, LCA Calculator, LCA4Waste (the-ecoinvent-association/software-tools/, n.d.)

In this project, the main purpose is:

- To browse systems and materials to find **optimal systems** based on different parameters.

- To make synthesis by drawing **charts** (optimal strategies) for height, typical loading, material, type of environment.

- To make a comparison between using or not using **digital fabrication**.

Bibliography

Richardson S., Hyde K. and Connaughton J., 2018. “Uncertainty Assessment of Comparative Design stages Embodied Carbon Assessments” in Embodied Carbon in Buildings (Pomponi F., De Wolf C., Moncaster A.[Eds.]), Springer.

Helal, James, André Stephan, and Robert H. Crawford. 2020. "The influence of structural design methods on the embodied greenhouse gas emissions of structural systems for tall buildings." Elsevier Ltd 650-665.

Tighnavard Balasbaneh, Ali, and Abdul Kadir Bin Marsono. 2017. "New residential construction building and composite post and beam structure." Environmental Progress & Sustainable Energy.

Abolghassem Tehrani, Maryam, and Thomas Froese. 2017. "A COMPARATIVE LIFE CYCLE ASSESSMENT OF TALL BUILDINGS WITH ALTERNATIVE STRUCTURAL SYSTEMS: WOOD VS. CONCRETE." Vancouver.

Beton, 248. 2020. "Hoge gebouwen/Bâtiments de grand hauteur." BETON Magazine. https://beton.febe.be/beton-online/beton-248/.

Bob Sheil, Mette Ramsgaard Thomsen, Martin Tamke, and Sean Hanna, ed. 2020. Design Transactions; Rethinking Information Modelling for a New Material Age. UCL press.

Bruce-Hyrkäs, Tytti, Panu Pasanen, and Rodrigo Castro. 2018. "Overview of Whole Building Life-Cycle Assessment for Green Building Certification and Ecodesign through Industry Surveys and Interviews." 25th CIRP Life Cycle Engineering (LCE) Conference. Copenhagen. 178 – 183.

Caruso, Maria Chiara , Marco Lamperti Tornaghi, and Paolo Negro. 2017. Applicability of the Sustainable Structural Design (SSD) method at urban/regional/national level. Technical report, Italy: European Union.

Gengnagel, Christoph, Olivier Baverel, Jane Burry, Mette Ramsgaard Thomsen, and Stefan Weinzierl, . 2019. Impact: Design With All Senses; Proceedings of the Design Modelling; Symposium, Berlin 2019. Berlin: Springer.

Heinrich, Mattias, and Warner Lang. 2019. Materials passports - Best Practice; Innovative Solutions for a Transition to a Circular Economy in the Built Environmet. Munchen: Technische Universitat Munchen, in association with BAMB .

Helal, James , André Stephan, and Robert H. Crawford. 2018. “Beyond the ‘premium-for-height’ framework for designing structural systems for tall buildings: considering embodied environmental flows.” 52nd International Conference of the Architectural Science Association. The Architectural Science. 241-248.

Helal, James, André Stephan, and Robert Crawford. 2019. Towards a design framework for the structural systems of tall buildings that considers embodied greenhouse gas emissions. London.

Herczeg, Dr. Márton, David McKinnon, Leonidas Milios, Ioannis Bakas, Erik Klaassens, Dr. Katarina Svatikova, and Oscar Widerberg. 2014. "Resource efficiency in the building sector." Rotterdam.

Julie Lyslo Skullestad, Rolf André Bohne, Jardar Lohne. 2016. "High-Rise Timber Buildings as a Climate Change Mitigation Measure - A Comparative LCA of Structural System Alternatives." SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep,. Elsevier Ltd. 112-123.

Karen Allacker (KU Leuven), Wim Debacker (VITO), Laetitia Delem (BBRI), and Leo De. 2018. Environmental profile of building elements. Brussels: OVAM, Stationsstraat 110, 2800 Mechelen.

Kaspersena, Benedicte , Jardar Lohne, and Rolf André Bohne. 2016. "Exploring the CO2-Impact for Building Height; A Study on Technical Building Installations." Energy Procedia 5 – 16.

Lankhorst, Gerran J., Janko Arts, Karel C. Terwel, and Henk M. Jonkers. 2019. "Life Cycle Analysis: Load-Bearing Structures Of High-Rise Buildings in Western Europe." CTBUH Journal Issue III 28-35.

Lemercier, Elisabeth. 2020. INTELLIGENT FABRICATION 2020; Timber Patterning. ONLINE LECTURE SERIES, ENSAV LAB; intelligent fabrication. https://ensavlab.wixsite.com/ensavlab/2020.

Lokhandwala, Zaheed. 2018. "Computational Design with Reused Materials."

Mabilde, Julie. 2020. ""Brussels, compact city", ." A+ 278, 5 5. https://www.a-plus.be/fr/projet/brussels-compact-city/.

Mavrokapnidis, Dimitris, Nikos Lagaros, and Chara Ch. Mitropoulou. 2019. "Environmental assessment of cost optimized structural systems in tall buildings." Journal of Building Engineering.

Meticulous Research®. 2020. "Automation Industry Amid Global COVID-19 (Coronavirus) Crisis:." Meticulous Market Research Pvt. Ltd., May 12. https://www.meticulousresearch.com/covid-19-article/automation-industry-amid-global-covid-19-crisis.

Moncaster, A.M., F Pomponi, K.E Symons, and P.M Guthrie. 2018. "Why method matters: Temporal, spatial and physical variations in LCA and their impact on choice of structural system." Energy & Buildings.

Nations, United. 2019. World Population Prospects 2019: Highlights. Department of Economic and Social Affairs, Population Division, New York: United Nations.

OVAM. update 2020. Environmental profile of building elements. OVAM, Stationsstraat 110, 2800 Mechelen.

Park, Hyo Seon , Bongkeun Kwon, Yunah Shin, Yousok Kim, Taehoon Hong, and Se Woon Choi. 2013. “Cost and CO2 Emission Optimization of Steel Reinforced Concrete Columns in High-Rise Buildings.” energies 5609-5624.

Putro, Hendro Trieddiantoro, and Wiliarto Wirasmoyo. 2019. "The Application of Digital Fabrication in Architecture, Case Study: Prototyping a Scale Model." EduARCHsia & Senvar 2019 International Conference (EduARCHsia 2019).

Raimund Bleischwitz, Bettina Bahn-Walkowiak. 2006. "Sustainable Development in the European aggregates industry: a case for sectoral strategies." Berlin Conference on the Human Dimensions of Global Environmental Change.

Review, Quadrennial Technology. 2015. "Quadrennial Technology Review: AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES." Energy.Gov. https://www.energy.gov/quadrennial-technology-review-2015.

Robert Patz, Monika Grzymala and Christoph Gengnagel. 2019. "Bodily Design Processes in Immersive Virtual Environments."

Rolf André BOHNE, Benedicte KASPERSEN, Julie LYSLO SKULLESTAD, Egil YTREHUS. 2017. "Embodied Energy Versus Building Height, The “Premium” of Building Tall." World Sustainable Built Environment Conference. Hong Kong. 1992-1997.

Romano, Elvira , Paolo Negro, and Fabio Taucer. 2014. Seismic performance assessment addressing sustainability and energy efficiency. JRC SCIENTIFIC AND POLICY REPORT, Luxembourg: European Union.

Trabucco, Dario , and Antony Wood. 2016. "LCA oftallbuildings:Stillalongwaytogo." Journal ofBuildingEngineering 379-381.

Tsimplokoukou, Kassiani , Marco Lamperti, and Paolo Negro. 2014. Building Design for Safety and Sustainability. JRC SCIENCE AND POLICY REPORTS, European Union.

UN Environment and International Energy Agency. 2017. Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report.

Ying Liu, Haibo Guo , Cheng Sun and Wen-Shao Chang. 2016. "Assessing Cross Laminated Timber (CLT) as an Alternative Material for Mid-Rise Residential Buildings in Cold Regions in China—A Life-Cycle Assessment Approach." sustainability. www.mdpi.com/journal/sustainability.

Evy Slabbinck 2020. INTELLIGENT FABRICATION 2020; What can wood do? Free form edition. ONLINE LECTURE SERIES, ENSAV LAB; intelligent fabrication. https://ensavlab.wixsite.com/ensavlab/2020.

Thank you for your consideration