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### Benchmark of ecodesign LCA tools at neighborhood scale

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#### Context

- LCA is a well-known methodology used for ecodesign purpose now applied on complex systems such as neighborhoods (Lotteau 2017).
- Cities being responsible for “two-thirds of global energy consumption and more than 70% of annual global carbon emissions” (IEA 2021).
- Need to reduce their impacts and adapt to climate change.
- Urban projects are unique long-lasting systems in close interaction with their environment.
- Specific tools are needed during early stage of urban project design.
- Major research effort has been deployed on the regionalization and spatialization of LCAs (Patouillard et al. 2018).
- BIM, CIM, GIS or even digital twins are blooming and represent an interesting new source of data.
- These data can be used to increase accuracy and usability of LCA ecodesign tools.

#### Purpose

- Present a review of LCA tools at neighborhood scale
- Identify tradeoffs between accuracy, usability, adaptability and completeness
- Suggest levers to improve tool accuracy, usability, adaptability and completeness
- Propose research perspectives thanks to identified blind spots in ecodesign LCA tools

#### Methodology for tool corpus creation

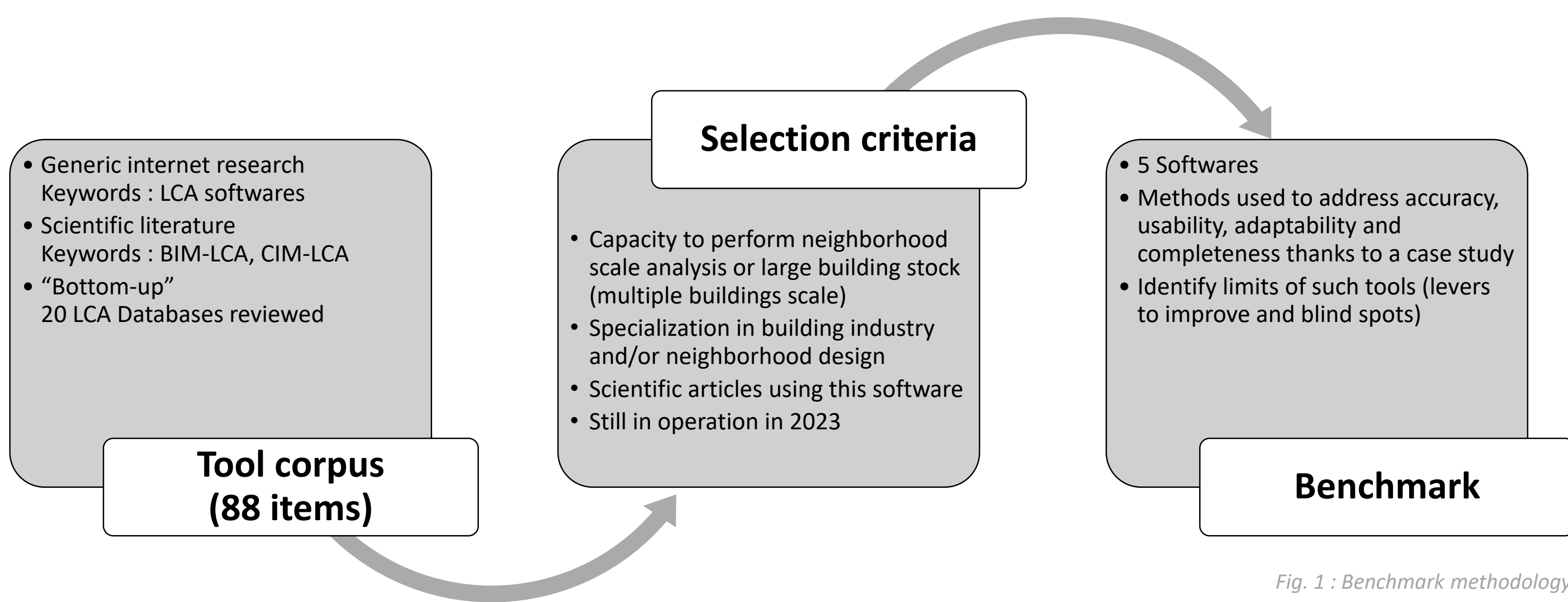


Fig. 1 : Benchmark methodology

#### Case study presentation

Our case study is based on “La Vallée” neighborhood located in Châtenay-Malabry, France.

##### Key figures:

- 20.6 Ha
- Started in 2018, under construction until 2027
- BIM+ Model available
- 152.403m<sup>2</sup> floor area for residential needs, equivalent of 2.225 dwellings
- 39 500m<sup>2</sup> floor area for offices
- 15.050m<sup>2</sup> floor area of commercial spaces
- 3 scholar groups (a crib, a secondary and high school)
- 1 gymnasium
- 1 urban farm of 1 hectare
- 1 parking of 450 places
- 8 hectares of green spaces private and public combined

A simplified 3D model is created based on data from the urban planning phase.

This model is created with volumes in the Revit software (Fig. 2).

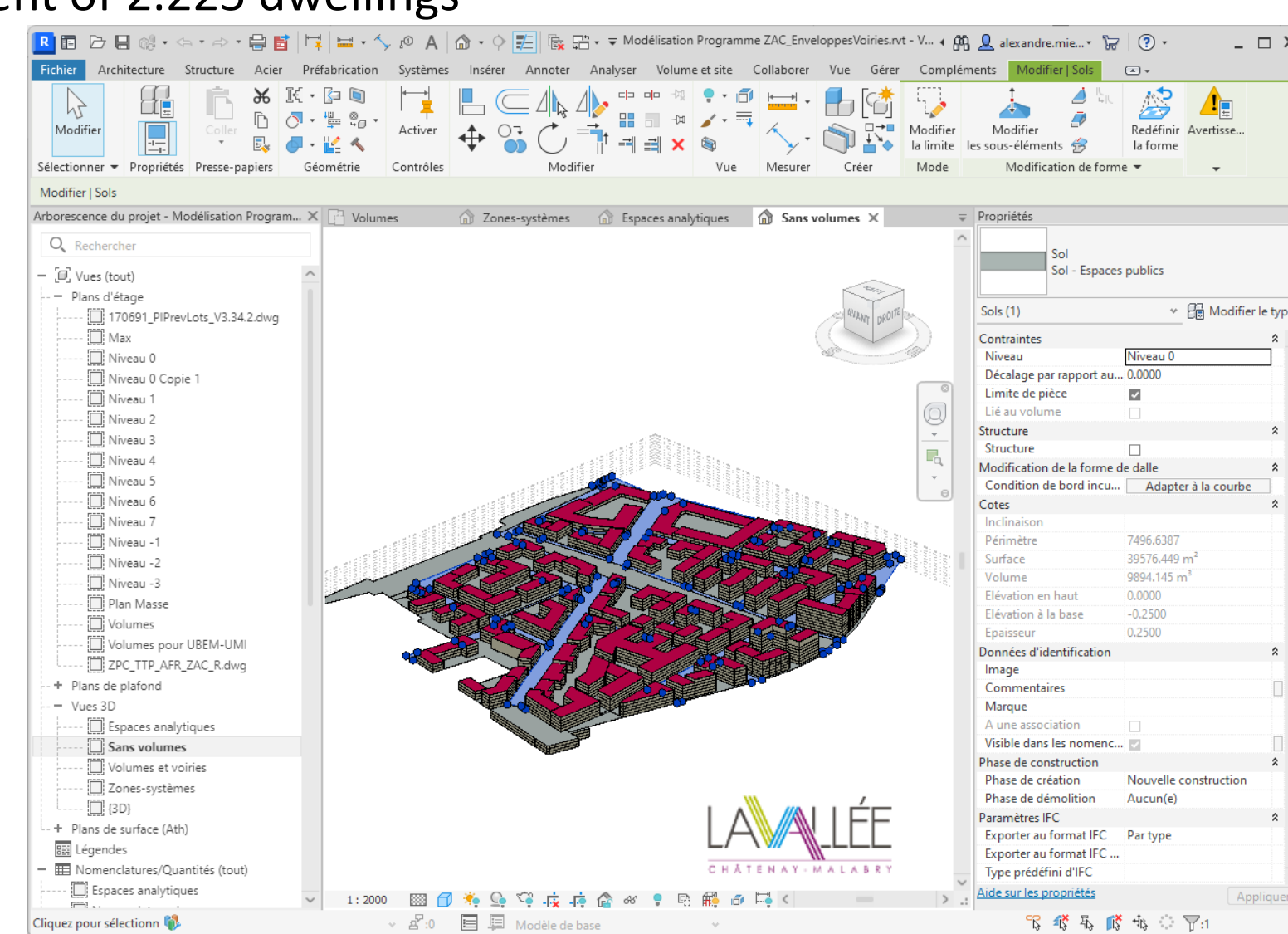


Fig. 2 : Case study modeled in Revit

#### Qualitative analysis

Pléiades (EQUER)	SimStadt2	Sméo	UBEM + UMI	Urban Print
<ul style="list-style-type: none"> <li>Take into account environmental impact linked to building, mobility, open spaces, infrastructure networks and on-site energy.</li> <li>Strategy aims at providing a tool for design offices that need to perform detailed analysis of projects.</li> <li>Specialty in buildings thermal analysis but requires experts to do so.</li> </ul>	<ul style="list-style-type: none"> <li>Focus on building and infrastructure networks.</li> <li>Strategy is based on visual programming, by connecting processes in chain to perform desired calculation.</li> <li>Each calculation value input can be customized.</li> </ul>	<ul style="list-style-type: none"> <li>Focus on building, mobility, open spaces, social needs and economic indicators.</li> <li>Strategy based on providing simple and precise information to help non-specialist analyze and grade a project.</li> <li>No thermal nor energy dynamic simulation</li> </ul>	<ul style="list-style-type: none"> <li>Focus on building, mobility, open spaces, on-site energy and economic indicator.</li> <li>Modeling strategy associated with the Rhino software makes it a very interesting tool for early stage conception since Rhino is a well-known tool amongst architects and urban planners.</li> <li>Uses archetypes to define buildings physical properties.</li> </ul>	<ul style="list-style-type: none"> <li>Take into account environmental impact linked to building, mobility, open spaces, infrastructure networks and on-site energy.</li> <li>Calculation focus on French standards compliance.</li> <li>User is guided all along the calculation process, few choices are possible and based on default values.</li> <li>Capability to gather information from GIS sources, making data collection and operation direct.</li> </ul>

#### References

- « Empowering Cities for a Net Zero Future – Analysis ». 2021. IEA. 2021. <https://www.iea.org/reports/empowering-cities-for-a-net-zero-future>.
- Lotteau, Marc. 2017. « Développement d'une approche d'intégration des questions de morphologie urbaine dans l'évaluation environnementale des projets d'aménagement à l'échelle du quartier basée sur l'analyse de cycle de vie ». Phdthesis, Université de Bordeaux. <https://tel.archives-ouvertes.fr/tel-01677273>.
- Patouillard, Laure, Cécile Bulle, Cécile Querleu, Dominique Maxime, Philippe Osses, et Manuele Margni. 2018. « Critical Review and Practical Recommendations to Integrate the Spatial Dimension into Life Cycle Assessment ». *Journal of Cleaner Production* 177 (mars): 398-412. <https://doi.org/10.1016/j.jclepro.2017.12.192>.

#### Results – Review of LCA tools at neighborhood scale

- Most of the tool corpus are dedicated to single building (i.e. not capable to perform LCA of complex urban project) or products LCA
- 5 tools benchmarked ≈ 6% of the total tool corpus : **Pléiades, SimStadt2, Sméo, UBEM & UMI and Urban Print**

	Pléiades (EQUER)	SimStadt2**	Sméo	UBEM + UMI	Urban Print
<b>Target audience</b>	Building designers (Architects and engineers)	Architects, engineering offices, urban planners and municipalities	Urban planners and municipalities thanks to Building designers	Architects, engineering offices, urban planners and municipalities	Urban planners and municipalities thanks to Building designers
<b>Phase usability</b>	Early and advanced design phase + Existing stage >10 indicators covering all three areas of protection : human health, biodiversity and natural resources	Early design phase + Existing stage	Early and advanced design phase	Early design + Existing stage	Early and advanced design phase + Existing stage >10 indicators covering all three areas of protection : human health, biodiversity and natural resources
<b>LCA Indicators and natural resources</b>	Primary Energy, GWP*	NRE*, GWP*, UBP*	NRE*, GWP*	NRE*, GWP*	
<b>Papers or Articles</b>	Yes	Yes	Yes	Yes	Communication
<b>Calculations based on 3D Models</b>	Yes – Link with IFC and citygml	Yes – Link with citygml	No	Yes – Link with .geojson/.gpkg or « Solid 3D models + Archetypes	Yes – Linked with french GIS information, geojson

\*NRE : Non-Renewable Energy ; GWP : Global Warming Potential ; UBP : Umwelt Belastung Punkten = Environmental Pollution Points

\*\*We haven't been able to perform an analysis based on any case study, so the results presented for SimStadt are based on it's documentation

#### Results - Tradeoffs between accuracy, usability, adaptability and completeness

- Accuracy** : capability to modify values for the calculation of the equipment energy performance as well as the exact composition of the built elements of a district
- Usability** : effectiveness, efficiency and satisfaction with which was possible to complete an analysis based on our case study
- Adaptability** : ability of the tool to modify its calculations according to the needs of the study
- Completeness** : capability to take into account environmental impact linked to building, mobility, open spaces, infrastructure networks, on-site energy, socio-economics or other factors
- Gradation ranges from 0 to 2 :  
2 = Best option  
1 = Possible but not the best option  
0 = Not possible

Summing each gradation and normalizing it depending on the maximum result possible, we obtained the following graph (fig.3).

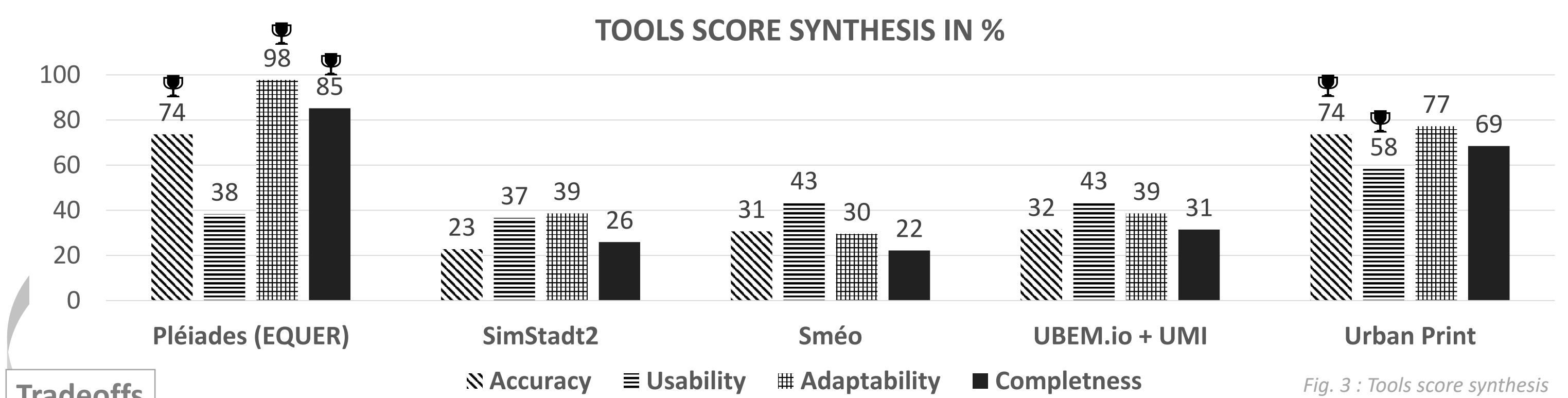


Fig. 3 : Tools score synthesis

#### Results - Levers to improve tool accuracy, usability and adaptability

	Levers to improve	Examples
<b>Accuracy</b>	<ul style="list-style-type: none"> <li>Link with GIS data</li> <li>Variety of LCA indicators</li> <li>Calculation capabilities</li> <li>User interface/experience</li> <li>Results visualization/presentation</li> <li>Design assistance tools</li> <li>Link with 3D models</li> <li>Exportation capabilities</li> </ul>	<ul style="list-style-type: none"> <li>Link with GIS and BIM to gather information</li> <li>Ratio of apartments typology : (T1/T2/T3/etc.) %/floor area ; Food production ; Taking into account economically active area ; Used water management, water demand for buildings and land fields</li> </ul>
<b>Usability</b>	<ul style="list-style-type: none"> <li>Link with GIS data</li> <li>Variety of LCA indicators</li> <li>Calculation capabilities</li> <li>User interface/experience</li> <li>Results visualization/presentation</li> <li>Design assistance tools</li> <li>Link with 3D models</li> <li>Exportation capabilities</li> </ul>	<ul style="list-style-type: none"> <li>Open spaces custom layers composition ; Incineration, cogeneration calculation ; Solar potential, photovoltaic production calculation</li> <li>Use archetypes to define building properties</li> <li>Bar charts, donuts, maps and LCA indicators spatialization</li> <li>Proportion of possible upgrades depending on calculation</li> <li>Automated modeling from GIS or BIM Models ; District heating network layout suggestion</li> <li>Proposing exports in PDF, document and spreadsheet formats</li> <li>Capability to detail the phase of LCA : focus on cradle to gate only for example</li> <li>Functional mix, Local economy, Open spaces (in particular green spaces), Economic viability, Waste and Water management</li> </ul>
<b>Adaptability</b>	<ul style="list-style-type: none"> <li>LCA phase segmentation</li> <li>Widen the scope of studied elements</li> <li>LCA duration</li> <li>Standards</li> <li>On-site energy production</li> <li>Economic indicators</li> <li>Mobility indicators</li> <li>Open spaces indicators</li> <li>Waste analysis</li> <li>Equipment's sizing capabilities</li> <li>Modeling capabilities (i.e. detailed modeling)</li> </ul>	<ul style="list-style-type: none"> <li>Capability to adjust lifetime for LCA calculation</li> <li>Proposing different standards for calculation, national and international ones</li> <li>Photovoltaic production calculation ; District heating network sizing</li> <li>Taking into account economically active area</li> <li>Walkability or cyclability of a neighborhood</li> <li>Trees positions, size, species / deciduous ; Layers compositions properties</li> <li>Household waste, waste collection</li> <li>Proposing possible upgrades depending on calculation</li> <li>Provide modeling capabilities to add geometry details and information to the 3D model</li> </ul>
<b>Completeness</b>	<ul style="list-style-type: none"> <li>LCA phase segmentation</li> <li>Widen the scope of studied elements</li> <li>LCA duration</li> <li>Standards</li> <li>On-site energy production</li> <li>Economic indicators</li> <li>Mobility indicators</li> <li>Open spaces indicators</li> <li>Waste analysis</li> <li>Equipment's sizing capabilities</li> <li>Modeling capabilities (i.e. detailed modeling)</li> </ul>	<ul style="list-style-type: none"> <li>Provide modeling capabilities to add geometry details and information to the 3D model</li> </ul>

#### Synthesis & Research perspectives

##### Research perspectives:

- LCA & Geospatial Data (BIM, CIM, GIS and related formats) coupling improvements** could ease data gathering and reduce uncertainty for LCA analysis.
- Tools must be capable to assist municipalities and decision makers before the design stages to build strategy for neighborhood environmental impact reduction.
- During design early design phases, tools must be fast and allow easy modification to let a diversity of development options to be explored. But a risk of improving usability is to lower completeness and adaptability, this needs to be avoided as much as possible.
- We can also see that socio-economic factors and open spaces and in particular green spaces (specifically trees) could be better implemented in those tools.
- Geovisualization of LCA impacts is not currently supported by any of the benchmarked tools. However, the incorporation of such visualization could provide LCA specialists with valuable insights into the locations where different scenarios exhibit significant impacts.
- Finally, the multidisciplinary nature of a neighborhood needs a coherent and wide set of indicators, avoiding pollution displacement and representing all the protected areas, thus the tool used must be able to take into account a wide variety of thematic.
- The benchmark is based on one person using each software to perform the same case study. To complete our usability analysis, standards such as ISO 25010 should be used.