Annex I

Table summarizing the progress reached for each of the tasks involved in the project and proposals for future steps.

	Progress			Notes	Reliability	Difficulties / hinders	How to improve			
	(	0 1 2	3 4 5 6		L M H A		Short term / little effort	Medium term / effort	Long term / big effort	
							Preliminary work			
	٧٠.			Interpretation and formalization of the two regulations, with		High uncertainty and ambiguity	Collaboration with municipality officers	Find patterns in the regulations texts by means of natural language processing techniques	Huge collaboration (e.g. many cities / nation-wide)	
ation	As-is inv			the help of municipality officers.		in the text (even for human understanding )	Outcome: unique interpretation of the regulations	Outcome: Analysis of regulation and development of mechanisms to extend the formalization	Outcome: New regulations machine readable/easily formalizable	
Regulations interpretation and formalization	GL GL		Initial suggestions about how to support regulation formalization.		Outside the project core scope.	Collaboration between developers and municipality officers	Experts in formal language for rules to be involved  Collaboration between developers, municipality officers and legal people	Agreements by many cities / nation-wide		
s interpretat							Outcome: Criteria to follow when writing regulations to avoid ambiguity <sup>1</sup>	that both developers as well as	Outcome: Standardized and scalable criteria to formalize and write machine-readable rules	
Regulation	pl.		In this case, it was completely manual.		High uncertainty and ambiguity in the text (even for	Collaboration between developers and municipality officers	Implementation of the formalization methods agreed as guidelines  Systematic test on several regulations	Complete implementation of the formalization methods agreed as guidelines and systematic, tested use of them (by municipalities and by tools.		
	lmpl.					human understanding )	Outcome: Manual implementation of other regulations	Outcome: Tool assisting the translation of the regulation written according to the guidelines to machine readable code.	Outcome: Automatic integration tool-machine readable regulations (e.g. new regulations are very easily implemented).	

https://digitalagencynetwork.com/9-tips-to-avoid-ambiguity-when-writing-requirements-for-a-web-project/ https://www.aclweb.org/anthology/Y98-1027.pdf
 https://en.wikipedia.org/wiki/Cucumber (software)#Gherkin language

	As-is				Analysis of the provided models w.r.t. criteria useful to checks and	Lack of automatic validation tools	Review and test of more models	Collaboration with designers	Integration of the application examples with new design cases / modelling techniques / standard releases
	٩			automation		Outcome: Outline of common problems and errors in BIMs	Outcome: Outline of problematic modelling cases and proposal of solutions.	Outcome: Consistent models up-to date with respect to the techniques.	
ty					Outline of common errors, Proposal of useful modelling criteria or objects storage	Partial view, short time for testing	Analysis of how the different inaccuracies affect the implementation of automatic tools.	Collaboration with designers and BIM modelers  Test of guidelines for modelling BIM to be used in tools	Extensive agreement on criteria to produce suitable IFC models
IFC models quality	19					Outcome: Modelling and validity criteria to be respected by IFC models in order to work with automatic tools.	Outcome: collection of "modelling patterns" how reoccurring situations that don't have an immediately clear mapping to IFC/BIM could be modelled.	Outcome: Agreements designers-developers- standard about how to model and  implement specific modelling and  their export to standardized format.	
					Manual inspection	Lack of clear constraints in IFC, different implementatio ns of IFC, few	Define and implement an initial set of tools to check certain model issues (and possibly fix some of them).	Extend the testing of the tool to several models, improve performance and increase the number of validation/fixing functionalities.	Improvement of BIM software and standard implementation, according to guidelines and agreements.
	lmpl.					designers' official best practices reflected in the IFC file	Outcome: Set of tools to validate, fix and control w.r.t. certain issues the exported IFC by BIM software	Outcome: Comprehensive set of tools to validate, fix and control the exported IFC by BIM software	Outcome: Full consistency of the exported IFC by BIM sw with standard and guidelines. Full control.
					Check models	L	L	Provide education and	
БC	S				georeferencing			documentation	
IFC models georeferencing	As-is							Outcome: Integration of training about georeferencing within design and BIM courses.	
odels gec					Define criteria according to literature and the needs of the	-	Comprehensive review of the ongoing research and filling of remaining gaps.	-	-
IFC m	G				project		Outcome: Comprehensive white paper on research and best practices about georeferencing IFC models.	-	-

	lmpl.			Manual change of parameters in the IFC STEP text		Outside the project core scope.	Review and improvement of existing tools; implementation of a GeoBIM procedure, using ground control points (GCPs) provided as geoinformation  Outcome: Improvement of the available tools to store georeferencing in a specific LoGeoRef  Own tool allowing the calculation	Automatic georeferencing of large models in projected CRS using the necessary reference points and	Full control of IFC georeferencing within BIM sw.  Outcome: BIM sw allowing a consistent and controlled georeferencing, according to the needed LoGeoRefs
							of georeferencing information from GCPs.	parameters, with full metadata.	
						Ched	k of the dimension regulation		
				Measurement of ground truth in the IFC models and outline of		Partial subjectivity	Collaboration with municipality officers and designers for a few cases	Collaboration with municipality officers and designers for several cases	Possible update and maintenance
- be	As-is			pitfalls for automation			Outcome: Outline of some criteria and parameters to be applied for certain cases (e.g. tolerance percentage, elements to be included/excluded, level of approximation, etc.)	Outcome: Outline of possible different criteria and parameters to be applied for more cases (e.g. tolerance percentage, elements to be included/excluded, level of approximation, etc.)	-
g envelo	GL			Outline of common errors, Proposal of useful		Huge variability of each building	Possible revision of modelling guidelines to support envelope extraction processing.	Possible revision of modelling guidelines to support flexible envelope extraction processing.	Possible update and maintenance
f building	0			modelling criteria or objects storage		features	Outcome: (Possible) specific section of IFC modelling guidelines	Outcome: Specific section of IFC modelling guidelines	-
Extraction of building envelope		bounding boxes or extraction of concave hull of storeys, tested uncertain the IFC models.	models. Different	Tests and evaluation of a few envelope extraction methods	Test of different methods within up- to-date checking tools  Alignment with different criteria extraction.	Improvement of previous tools			
	Impl.			study BIMs		representation paradigm between BIM (each element as a solid) and the needed one (one waterproof surface)	Outcome: Tool implementing the envelope extraction algorithms	Outcome: Flexible tool allowing different extraction criteria and levels of generalization	Outcome: Fully reliable envelope extraction based on specific application parameters, tested in various cases.

							Manual measurement in Revit			Slight uncertainty	Make specific implicit criteria explicit.	-	-
ght	As-is									about the needed reference points	Outcome: More specific (less ambiguous) regulation		
x heig							Definition of useful criteria and			-	Extend to all the similar regulations in Rotterdam	Extend to all the similar regulations in many cities	Possible update and maintenance
Measure Max height	GL						parameters				Outcome: Possible outline of specific criteria to be used in similar regulations	Outcome: Possible outline of specific criteria to be used in different regulations, requiring different parameters.	-
_	Impl.						Measurement based on the BIM			Integration with suitable geoinformation	Improve the reference to the 3D city model or other geospatial data	Test the tool for different regulations and possible different criteria, improve flexibility.	Possible update and maintenance
	_									needed	Outcome: Working GeoBIM tool	Outcome: Flexible tool	
			ľ			İ	Manual detection from				Extend to a significant sample of		
							facades orthogonal	1		-	models	-	-
	As-is						projections exported by Revit				Outcome: Outline of useful examples and observation and applied criteria for segmentation		
ntatio							Identification of possible criteria to			Generalization of discontinuity	Collaboration with municipality officers	Extend to all the similar regulations in many cities	Possible update and maintenance
Building segmentation	GL		formally define the discontinuities			detection criteria		Outcome: Agreed criteria to be used in segmentation	Outcome: Possible outline of specific criteria to be used in different regulations, requiring different parameters.	-			
Buil							Use the storeys overlap percentage to segment BIM into			Solid envelop extraction method	Implement a tool to segment arbitrary buildings with one criterion	Test the tool for different regulations and possible different criteria, improve flexibility.	Possible update and maintenance
	ldml				several parts.			needed	Outcome: Simple tool	Outcome: Flexible tool			
							M			Ol:P-t	NATION OF SECTION AND SECTION OF		
re of sight	S						Manual measurement in Revit			Slight uncertainty	Make specific criteria explicit.	-	-
Measure of base height	As-is									about the needed reference points	Outcome: More specific (less ambiguous) regulation		

	GL			Definition of useful criteria and parameters		-	Extend to all the similar regulations in Rotterdam in collaboration with municipality officers	Extend to all the similar regulations in many cities	Possible update and maintenance
	0						Outcome: Possible outline of specific criteria to be used in similar regulations	Outcome: Possible outline of specific criteria to be used in different regulations, requiring different parameters.	-
	Impl.			Inference from the IfcBuildingStorey.Elev ation attribute		building	Make the measurement based on the building envelope	Test the tool for different regulations and possible different criteria, improve flexibility.	Possible update and maintenance
	느					segmentation method needed	Outcome: More reliable tool.	Outcome: Flexible tool	-
				Manual measurement in Revit/Solibri Model		Variations in each storey.	Extend to a significant sample of models	-	-
ding parts	As-is			viewer			Outcome: Outline of useful examples and observation and applied criteria for possible uncertain cases.		
/o build				Definition of useful tolerances		-	Collaboration with municipality officers	Possible update and maintenance	Possible update and maintenance
of the tw	Э					Outcome: (Possible) Agreed criteria to be used in overlapping calculation			
Measure overlap of the two building parts	Impl.			Use of IfcStoreys' concave hulls.	3	Solid envelop extraction and building segmentation method needed	Improvement of the tool using the agreed criteria and different possible references (envelope/bounding box) and different approximations or statistical parameters.	Possible update and maintenance	Possible update and maintenance
							Outcome: Very reliable (A) tool.		
				Manual massurament		I Indoretandia a	Make appoific criteria avalisit (a.c.		
gs.				Manual measurement in Revit		of facades	Make specific criteria explicit (e.g. balconies, etc.).	-	-
Measure overhangs.	As-is					directions and reference points	Outcome: Outline of useful examples and observation and applied criteria for possible uncertain cases.		

<sup>3</sup> Easily potentially reached: based on statistical parameters instead that on human subjective judgment and approximation.

					Definition of useful criteria and			-	Definition of geoinformation requirements	Collaboration with municipality officers	Possible update and maintenance			
	GL				parameters				Outcome: Criteria needed for reference objects in geoinformation and unique reference with what written in regulations.	Outcome: (Possible) Agreed criteria to be used in overhangs calculation				
					The street directions are manually defined. By default, the directions are parallel to the edges of			Automatic calculation of façade directions, with suitable	Automatic reading of geospatial information	Test the tool for different regulations and possible different criteria, improve flexibility (e.g. non-rectangular buildings).	Possible update and maintenance			
	lmpl.				bounding box of the building.			connection with geoinformation	Outcome: GeoBIM tool automatically reading the direction reference from geoinformaton - selecting the considered planes according to such directions - checking the overhangs dimensions	Outcome: Improved flexible tool, reading the needed parameters and getting them from the data automatically.				
		Check of the parking regulation												
					Manual check of representation in Solibri Model viewer			building elements into	Review and test of more models	Collaborate with designers	Integrate the application examples with new design cases / modelling techniques / standard releases			
	့တ	As-is						several	Outcome:	Outcome:	Outcome:			
ents	As-i							models; manual search for the right IfcSpace to be considered	Outline of common inaccuracies in BIMs	Outline of problematic modelling cases and proposal of solutions.	Consistent models up-to date with respect to the techniques.			
easure apartments	GL As-i				Definition of useful criteria and parameters. One of the alternatives is			manual search for the right IfcSpace to be considered Further	BIMs					
d and measure apartments					criteria and parameters. One of the			manual search for the right IfcSpace to be considered Further investigation and testing	Agree on a specific representation for related IfcSpaces Propose a structured enumeration extension for IfcSpaces  Outcome:	Cases and proposal of solutions.  Outline of requirements supporting automatic computation of building	respect to the techniques.  Agreement designers-municipality- standardization and			
Find and measure apartments					criteria and parameters. One of the alternatives is proposed, trusting the use of suitably modelled lfcSpaces One alternative is proposed, trusting the use of modelled			manual search for the right lfcSpace to be considered Further investigation and testing needed.  Modelling is not based on official well-	Agree on a specific representation for related IfcSpaces  Propose a structured enumeration extension for IfcSpaces  Outcome: Criteria to be followed in modelling	Cases and proposal of solutions.  Outline of requirements supporting automatic computation of building units and related gross floor area.  Outcome: Criteria to be followed in modelling	respect to the techniques.  Agreement designers-municipality- standardization and implementation in software.  Outcome:			
Find and measure apartments					criteria and parameters. One of the alternatives is proposed, trusting the use of suitably modelled lfcSpaces One alternative is proposed, trusting the			manual search for the right lfcSpace to be considered Further investigation and testing needed.  Modelling is not based on	Agree on a specific representation for related IfcSpaces Propose a structured enumeration extension for IfcSpaces  Outcome: Criteria to be followed in modelling the IfcSpaces in the BIM Inclusion of the proposed	Cases and proposal of solutions.  Outline of requirements supporting automatic computation of building units and related gross floor area.  Outcome: Criteria to be followed in modelling the IFC  Automatic computation of building units (as IfcSpaces) and related	respect to the techniques.  Agreement designers-municipality- standardization and implementation in software.  Outcome: Affirmed best practice  Test tool in different settings/for			

	As-is				Manual check of representation in Solibri Model viewer		No official standard representation	Check more models.  Outcome:		
	⋖	4					available	Outline of used representations for parking spaces		
g places					Manual check of representation in Solibri Model viewer		Huge topic, lack of BIM modelling and design skills.	Collaboration with designers, BIM modelers and municipality officers	Test of guidelines for modelling BIM to be used in tools.	Extensive agreements on criteria to produce suitable IFC models, involving standardization entities and designers
Count parking places	GL						Several options could be available, a wider investigation should be necessary.	Outcome: Agreement on kind of representation necessary based on the level of detail and reliability and control required	Outcome: Specific section of IFC modelling guidelines	Outcome: Extensively agreed specific section of IFC modelling guidelines
	lmpl.						Uncertain representation	Automatic count of specific parking objects	Possible update and maintenance	Possible update and maintenance
							of parking places	Outcome: Simple tool		
								Additional Tasks		
ation	As-is							Review of bottom-up and top- down enumerations for building spaces and building functions	Feedback from stakeholders	Possible update and maintenance
enumeration	⋖							Outcome: Reference framework	Outcome: Suggestions for improvements	
								Suggestion of useful reference codelist values for IfcSpaces to support tools	Extension to support other cases	Integration and alignment standards
of useful IfcSpace	Э							Outcome: Recommended codelist	Outcome: Recommended codelist	Outcome: Standardised integrated codelist and defined subset definition for speficic cases.
Proposal	Impl.							Implementation of enumeration in own tools	Possible update and maintenance	Possible update and maintenance
Ш										

**Progress** 

	As-is investigation and description	Guidelines and requirements definition	Implementation of supporting tools
0	Not performed	Not performed	Not performed
1	Partial	Approximation, from the data of this case study.	Partial
2	Approximation, valid for this case study.	Approximation, from the data of this case study plus literature review	Approximation, valid for this case study and Boompjes BIM only
3	Valid for this case study, with related literature review.	Valid for this case study, consistent with related literature review.	Valid for this case study, with both BIMs
4	General findings scalable to any BIM	General guidelines and requirements scalable to many case studies.	Working procedure scalable to any BIM
5	General findings / methodology scalable to any BIM and any regulation of the same type	General guidelines and requirements scalable to many case studies [+ tested in tools /reviewed and agreed by stakeholders].	Working procedure scalable to any BIM and any regulation of the same type
6	A comprehensive investigation, reference for any similar task in any case study.	Guidelines and requirements reviewed and agreed by a high number of stakeholders and professionals, and tested in many tools.	The best procedure scalable to any BIM and any regulation of the same type

## **DEGREE** of reliability

A - Better result than human-based

H - High

M – Medium

L - Low