Introduction, Failure Assessment Publication

- Publication,
- Further look on the failure data
- Building information model BIM,

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Business from technology

Current status of the publication

- This report covers summaries of studies on structural failures on timber structures around Europe.
- Guidelines on implementing inspections on structures and on the building process concepts to obtain quality and avoid failures are given.
- Discuss the various failure assessment methods
- Agree on a common procedure to be used for future assessments: failure classification

1. Introduction, Toratti **(ready)**
2. Terminology used in the failure assessment **(not ready)** (Nordic &German), Frühwald & Frese
3. Failure assessments
   3.I Analysis of failures on timber structures in Germany, Frese & Blass **(ready)**
   3.II Design of timber structures, learning from failures, Frühwald & al. **(ready)**
   - Open for further presentations....
4. Guidelines
   4.I Guidelines for a first evaluation of large span timber structures, Kruetzinger **(ready)**
   4.II Guidelines for quality in the timber building process, Toratti, **(ready)**
5. Failure classification procedures
   5.I German study, Frese & Blass **(not ready)**
   5.II Nordic study, Frühwald & al. **(ready)**
   5.III Dutch example, Leijten **(not ready)**
   5.IV Drafting of European wide failure classification, **(future brainstorming)**
6. Discussion

Failure classification in the Nordic study

Give one or more reason for the failure by writing one or several numbers as follows 1= primary reason, 2= secondary reason , 3 = tertiary reason

- ❑ Poor design/lack of strength design
- ❑ Poor design/lack of design related to environmental actions
- ❑ Poor principles during construction
- ❑ Alterations on-site of intended design or products
- ❑ Deficiency of code rules for prediction of capacity
- ❑ Extreme loading exceeding code values
- ❑ Inadequate quality of wood material
- ❑ Poor manufacturing principles for wood products
- ❑ Manufacturing errors in factory
- ❑ Misuse or lack of maintenance of the structure
- ❑ Other, specify below

Overview of all cases with rating

Case	Material	Rating of failure causes									Source	page
		1	2	3	4	5	6	7	8	9		
1	ST					1					LS	52
2	ST				0.2		0.8				LS	53
3	GL						1				LS	54
4	GL						0.5	0.5			LS	55
5	GL	0.1				0.2	0.4	0.3			LS	57
6	GL					0.8		0.2			LS	59
7	GL					0.8	0.2				LS	61
8	GL					1					LS	63
9	GL					0.5	0.5				LS	64
10	GL					1					LS	65
11	ST	0.1				0.4		0.5			LS	66
12	GL					0.5		0.5			LS	68
13	Plywood							1			LS	69
14	GL						1				LS	71
15	ST							1			LS	73
16	Plywood, ST							1			LS	74
17	ST						1				LS	75
18	ST					0.7		0.3			LS	76

Further look of the failure cases in Finland

- Ludovic Fulop,
- Fully presented in Cost TU0601 Robustness of Structures

List of Cases with location of structure and date of incident

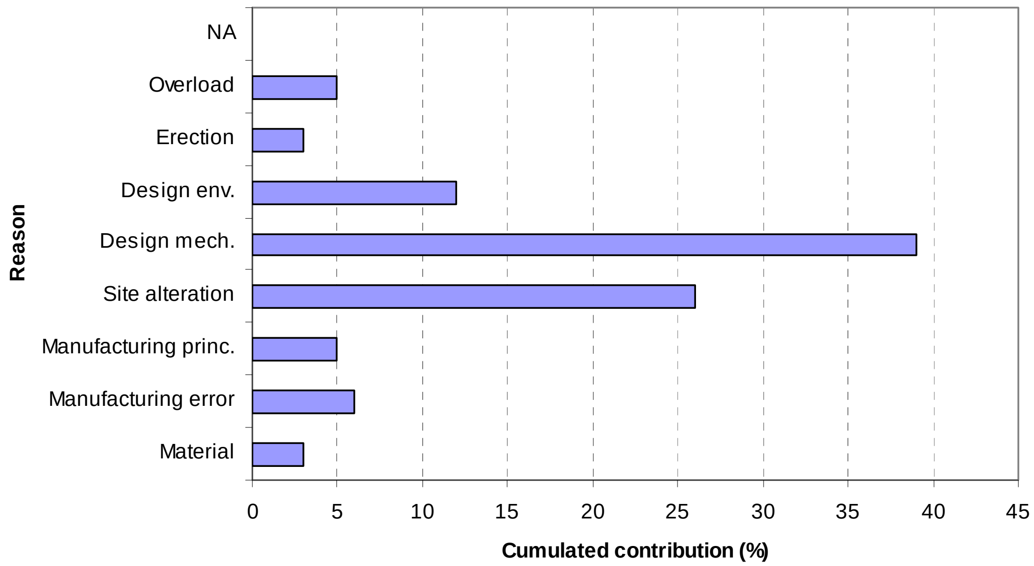
Case 1 – Fair Centre roof collapse, Jyväskylä (2003)
Case 2 – Collapse of glulam beam in industrial building (NA)
Case 3 – Collapse of industrial hall building (1999)
Case 4 – Collapsed glulam beam in swimming hall, Iisalmi (2000)
Case 5 – Collapsing of ceiling of supermarket (2000)
Case 6 – Overturn of glulam trusses during their installation (2001)
Case 7 – Roof collapse of market under construction (before 1995)
Case 8 – Roof collapse of manege (drill hall) (1996)
Case 9 – Collapse of new emergency exit of ice rink (2000)
Case 10 – Cow-house roof failure (2003)
Case 11 – Roof collapse of a beef cattle house (2004)
Case 12 – Failure of glulam beam, Vantaa (1997)
Case 13 – Failure of frames of single family houses, Kemijärvi (1992)
Case 14 – Failure of enlargement of industrial hall, Oulainen (NA)
Case 15 – Partial collapse of industrial hall, Pello (1991)
Case 16 – Partial collapse of roof of supermarket, Ranua (1998)
Case 17 – Collapse of roof of car store, Rovaniemi (1991)
Case 18 – Collapse of roof of industrial hall, Kitee (1982)
Case 19 – Collapse of roof of chicken farm, Alavus (1988)
Case 20 – Collapse of roof of industrial hall, Jyväskylä (1994)
Case 21 – Roof collapse of L-shaped building, Jämsä (1984)
Case 22 – Design error of roof trusses, Kemijärvi (NA)
Case 23 – Tilting of roof trusses, Mikkeli (1994)
Case 24 – Collapse of industrial L-shaped roof, Tampere (1992)
Case 25 – Failure of glulam arch, Heinola, Lahti, Laukaa (NA)
Case 26 – Curving of upper chord of roof truss, Hollola, (NA)
Case 27 – Damages in glulam beams, Laukaa, (2006)
Case 28 – Danger of roof collapse, Keitele, (2006)
Case 29 – Roof collapse of a Manege hall, Veteli, (2006)
Case 30 – Collapse of a Market roof, Haapajärvi, (2006)

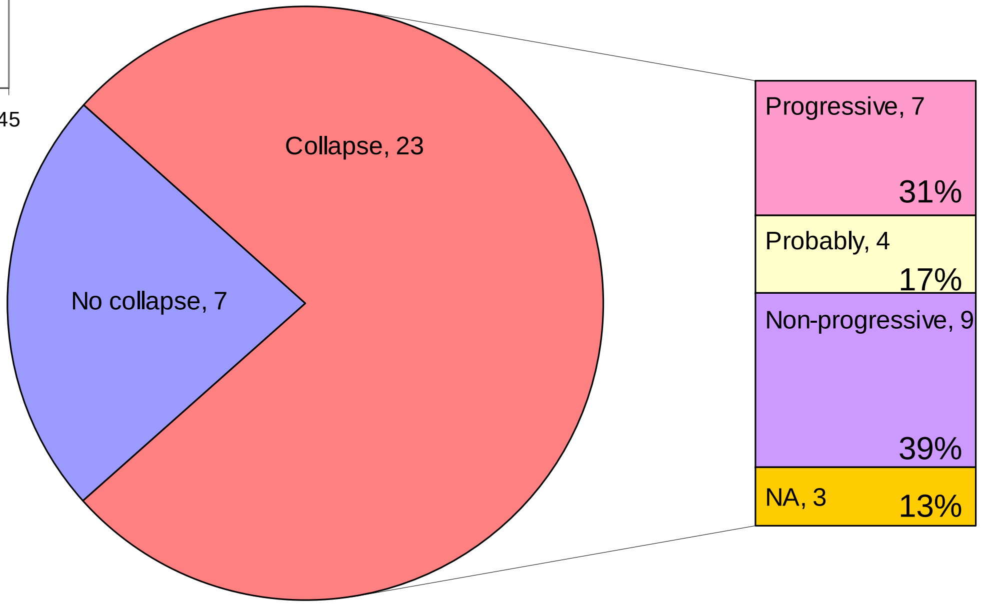
	Failing structural element	Trigger of failure	Collapse area (m^2)	Reason of failure/index (Toratti T.)	Reason 1	Reason 2	Reason 3	Progressive collapse?
1	GLULAM truss	Doweled truss connection	2500	Manufacturing error/ 0.8 Design mech./ 0.2	Faulty execution (7 dowels instead of 33)	Design code did not provide for the failure mode.	Designer did not document properly.	Yes
2	GLULAM beam	NA	- 1 beam	Design env./ 1	Long term exposure to heat			No
3	Nail-plate truss & columns	NA	2000	Design mech./ 1	Insufficient racking resistance			No
4	GLULAM beam	NA	NA	Design mech./ 1	Design mistake in reconstruction.	Snow-load (not excessive)		No
5	Ceiling strips	Nail-connection (withdrawal)	1700	Manufacturing principle/ 0.5 Design mech./ 0.5	Faulty execution	Design error (impossible to place nails)		No
6	Three-hinge arches	Overturning of 1 arch during erection	- 5 arches	Erection/ 1	Insufficient lateral support			Yes
7	Roof structure	Buckling of compressed chord	- total	Site alteration/ 0.5 Design mech./ 0.5	Lack of buckling support	Insulation weight increases due to moisture		Yes
8	Nail-plated truss	Buckling of compressed upper chord of central elevated part	- total	Site alteration/ 1	Faulty execution (deviation from design plan)	Snow (excessive)	Snow concentration	Yes (Trusses puling each other)
9	GLULAM cantilever	NA (Maybe LT-buckling)	NA	Design mech./ 1	Snow concentration			No
10	Nail-plate truss & C block walls	Buckling of upper chord (Lower chord failed later)	- total	Site alteration/ 0.5 Design mech./ 0.5	Lack of proper design	Snow (not excessive)		Yes

	Failing structural element	Trigger of failure	Collapse area (m^2)	Reason of failure/index (Toratti T.)	Reason 1	Reason 2	Reason 3	Progressive collapse?
11	Nail-plated truss & concrete walls	Failure of a compressed member in truss.	- collapsing of trusses stopped after 23m	Site alteration/ 0.5 Design mech./ 0.5	NA		Snow (not excessive)	Yes
12	GLULAM beam	Cracking of beam at hole	- one beam	Material/ 1	Bad quality timber? - (No clear explanation)			No
13	Nail-plate connected frames	NA	- no collapse.	Site alteration/ 0.8 Design mech./ 0.2	Design error.	Faulty execution of frame		No
14	Timber truss	NA	- 1/2 of the building	Site alteration/ 0.8 Design mech./ 0.2	Excessive snow.	Lack of bracing design.	Erection mistakes.	NA
15	Self-made nailed truss	NA	- 24 trusses	Site alteration/ 0.8 Design mech./ 0.2	Execution errors.			Probably
16	Nailed-plate trusses	NA	- 33 trusses	Site alteration/ 0.8 Overload/ 0.2	Execution errors (bracing, buckling support).	Snow load (excessive)		Probably
17	Prefabricated nail-plated trusses	Buckling of compressed diagonal.	300	Design mech./ 1	Manufacturing faults of nail-plate connections.	Lack of buckling support.	Snow load (not excessive)	NA
18	GLULAM beam	NA	NA	Overload/ 1	Snow load exceeding design value.			No
19	Nailed wooden truss	NA	-1/4 of roof area	Design mech./ 1	Top chord not supported by battens.	Lack of bracing in design.	Snow & ice.	No
20	Nailed wooden trusses	NA	- roof of the unheated part of the building	Design env./ 0.8 Overload/ 0.2	Snow (not-excessive).	Ice accumulation on truss members.	Moist timber.	No

	Failing structural element	Trigger of failure	Collapse area (m^2)	Reason of failure/index (Toratti T.)	Reason 1	Reason 2	Reason 3	Progressive collapse?
21	Glued timber trusses (double-member chords with single web)	NA	- total	Site alteration/ 0.2 Design mech./ 0.8	Buckling support for upper chord.	Lack of roof bracing.		Probably
22	Nail-plate trusses	-	- no collapse	Manufacturing error/ 1	Design mistake.			-
23	Wooden trusses	-	- no collapse	Design mech./ 1	Lack of bracing in design.	Trusses probably mounted obliquely.		Yes
24	Nailed plate trusses	NA (Maybe buckling of upper chord)	- one side of the L shaped roof	Site alteration/ 0.5 Design mech./ 0.5	Lateral support of upper chord not proper.	Lack of roof bracing.		Probably
25	GLULAM arches	-	- no collapse	Design env./ 1	Decay of unprotected timber			-
26	Wooden trusses	Buckling of upper chord.	- no collapse	Design mech./ 1	Lateral support of upper chord not proper.	Lack of proper design for the roof bracing.		-
27	GLULAM beams	Crack close column support.	- no collapse	Design env./ 1	Shrinkage of wood.	Snow (design value)		-
28	GLULAM beam	Inclined lamella glued connection failure.	- no collapse	Manufacturing principle/ 1	Insufficient knowledge at the time of construction.			-
29	Nail-plated trusses	NA	- total	Site alteration/ 0.5 Design mech./ 0.5	Stabilizing support of compression members missing (provided in design)	Lateral support of upper chord insufficient (with onduline only).	Lateral stability of building insufficient.	NA
30	Trusses supported by GLULAM beam on steel columns	Buckling of top chord of truss.	- in a 20 m area	Site alteration/ 1	Lateral support of upper chord insuficient.			Yes

Typology of structural failures





”Typical” progressive collapse scenario

- Local buckling of the upper chord (or other local failure) develops in a truss, due to the lack of lateral support of the chord.
- The failed truss drags other trusses, which are unable to resist the lateral force due to the lack of sufficient bracing.
- The ”domino” effect brings down the entire - or large part of the - truss roof.
- Possibly walls are also dragged by the roof trusses.
- Almost total collapse – or large part – of the structure occurs.

Conclusion

- Progressive collapse is a problem in Finland.
- Timber trusses with minimal bracing and lateral support are especially vulnerable.
- Better design rules to achieve more robust truss-roofs should be a goal.
- It is especially important that precise detailing solutions are provided to the designers. General statements in the code are often overlooked, or interpreted generously in ”real-life”.

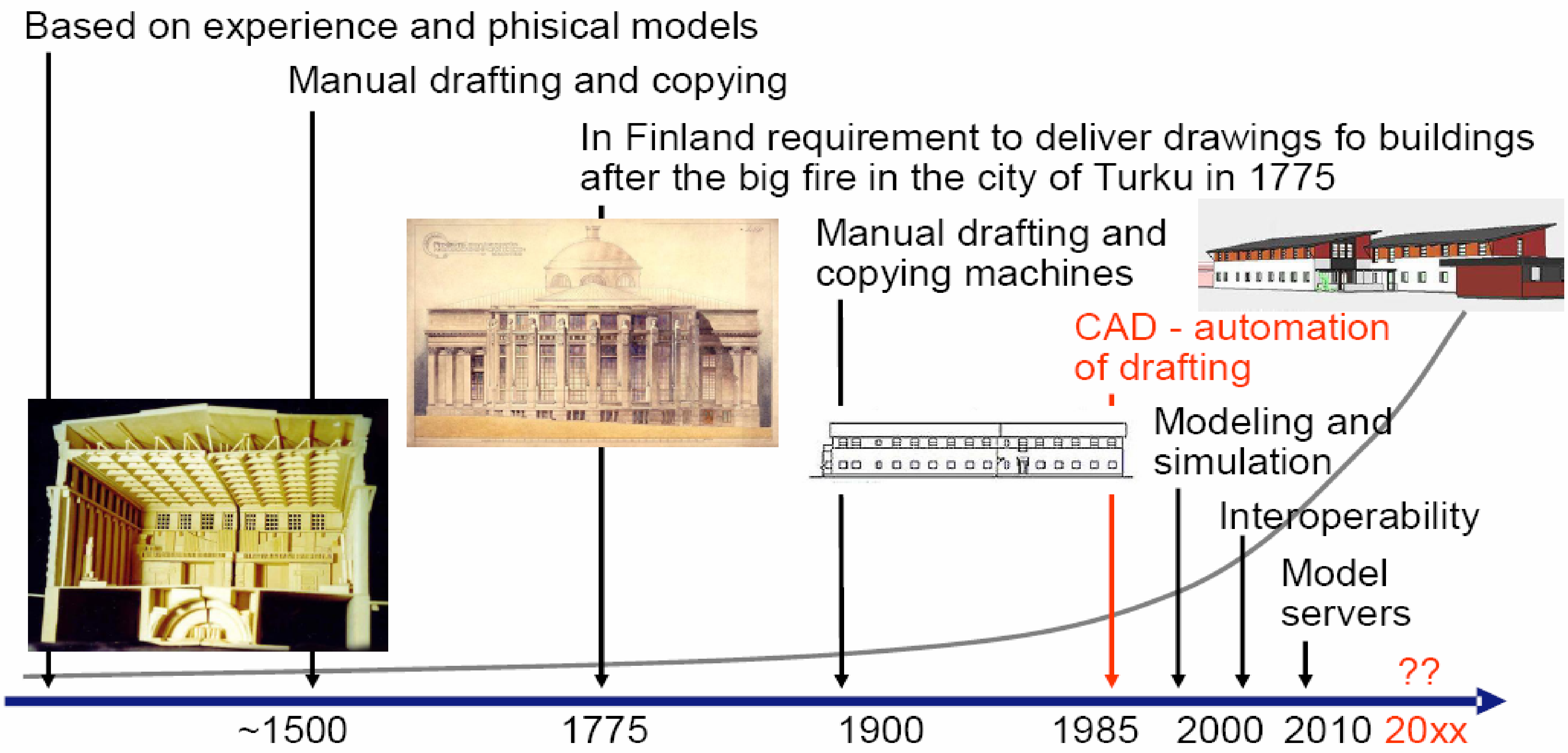
Building Information model, BIM

Why ?

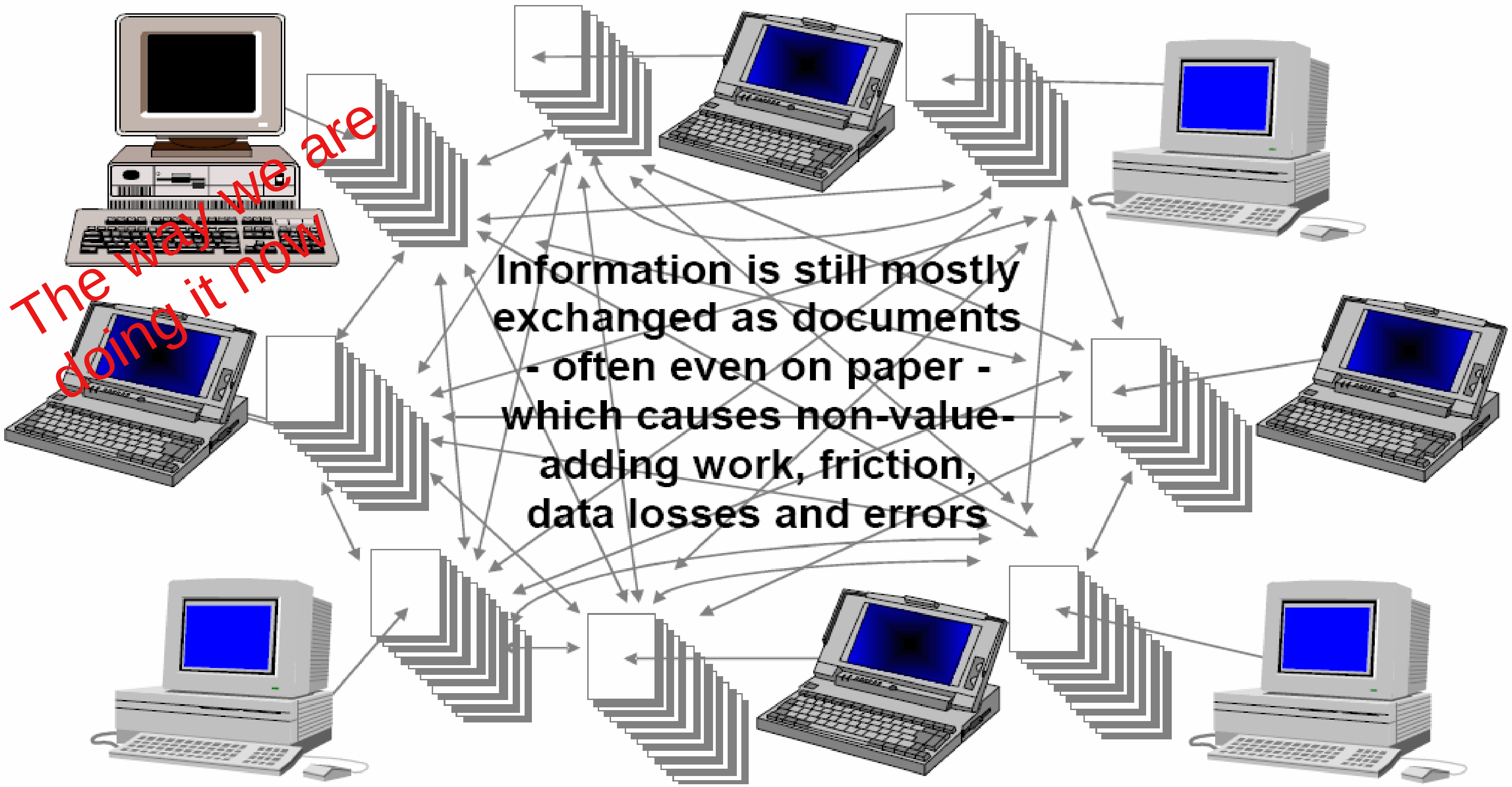
Current state of BIM development:

Steel structures most advanced,
Concrete structures coming behind
No activity for timber structures

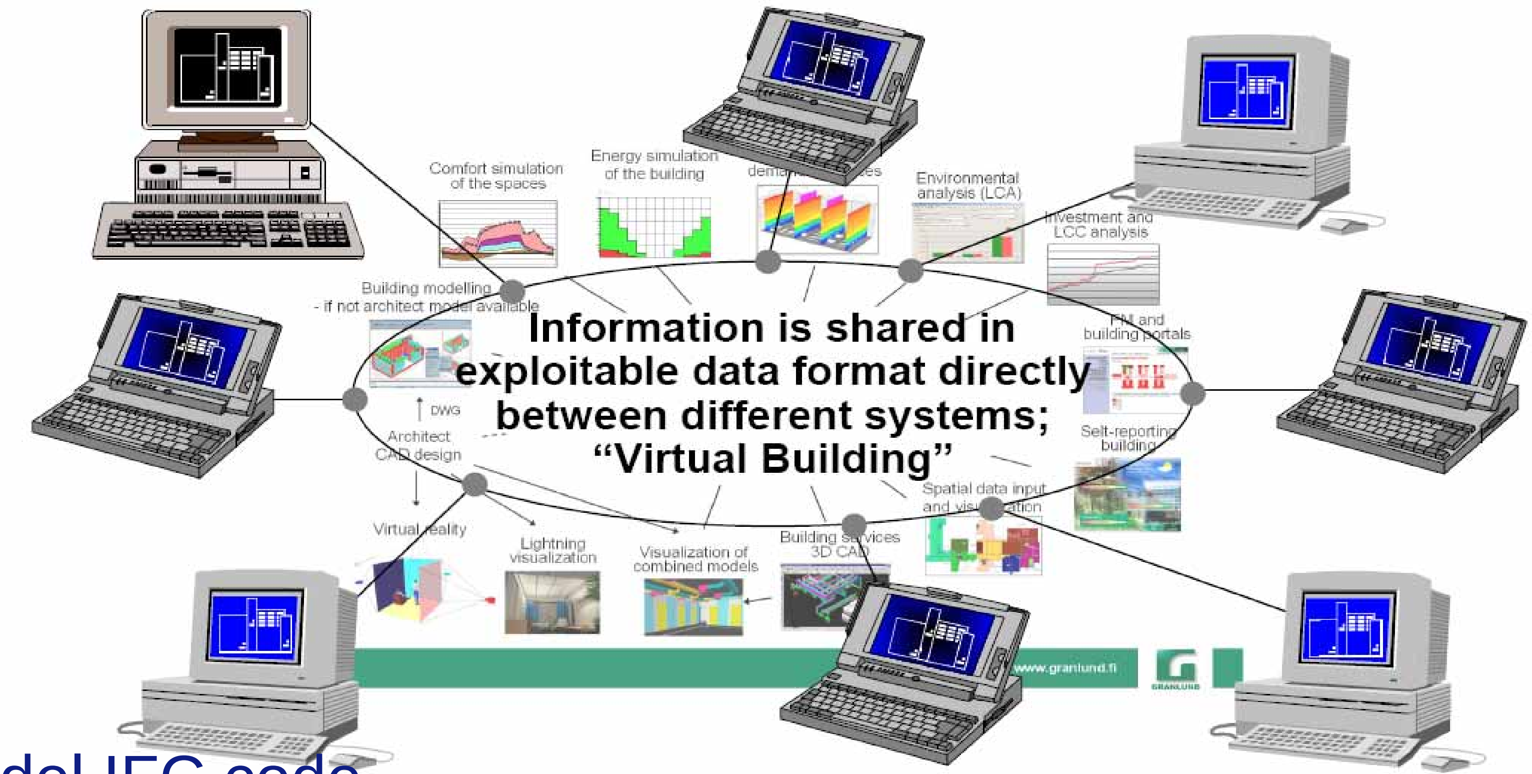
Technical Development of Building Design



Document/2D-based Process



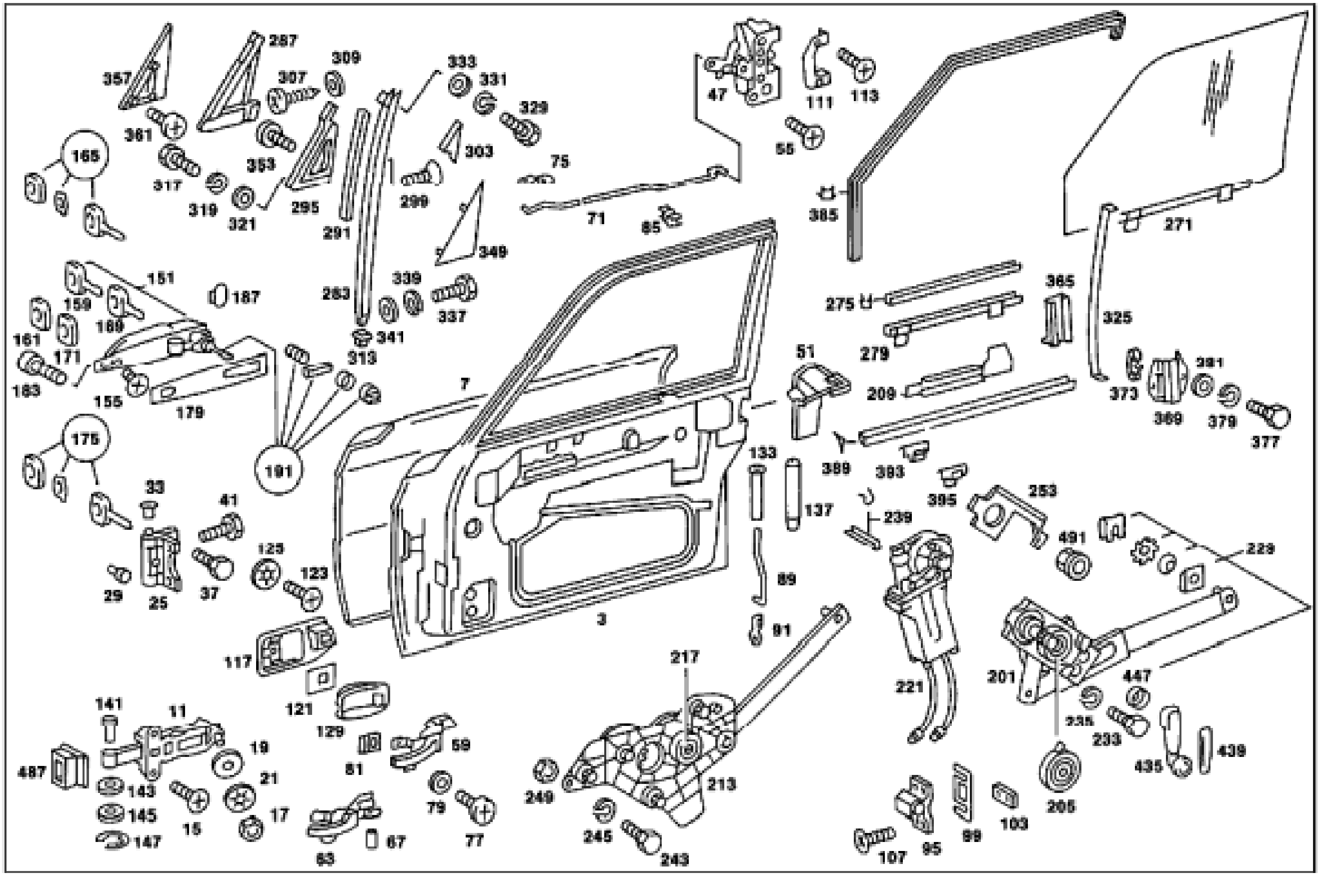
Integrated Model Based Process



Model IFC code

International alliance for interoperability (www.iai-international.org)

<u>Extension needs are determine for the IFC specification to consider structural design of timber buildings</u>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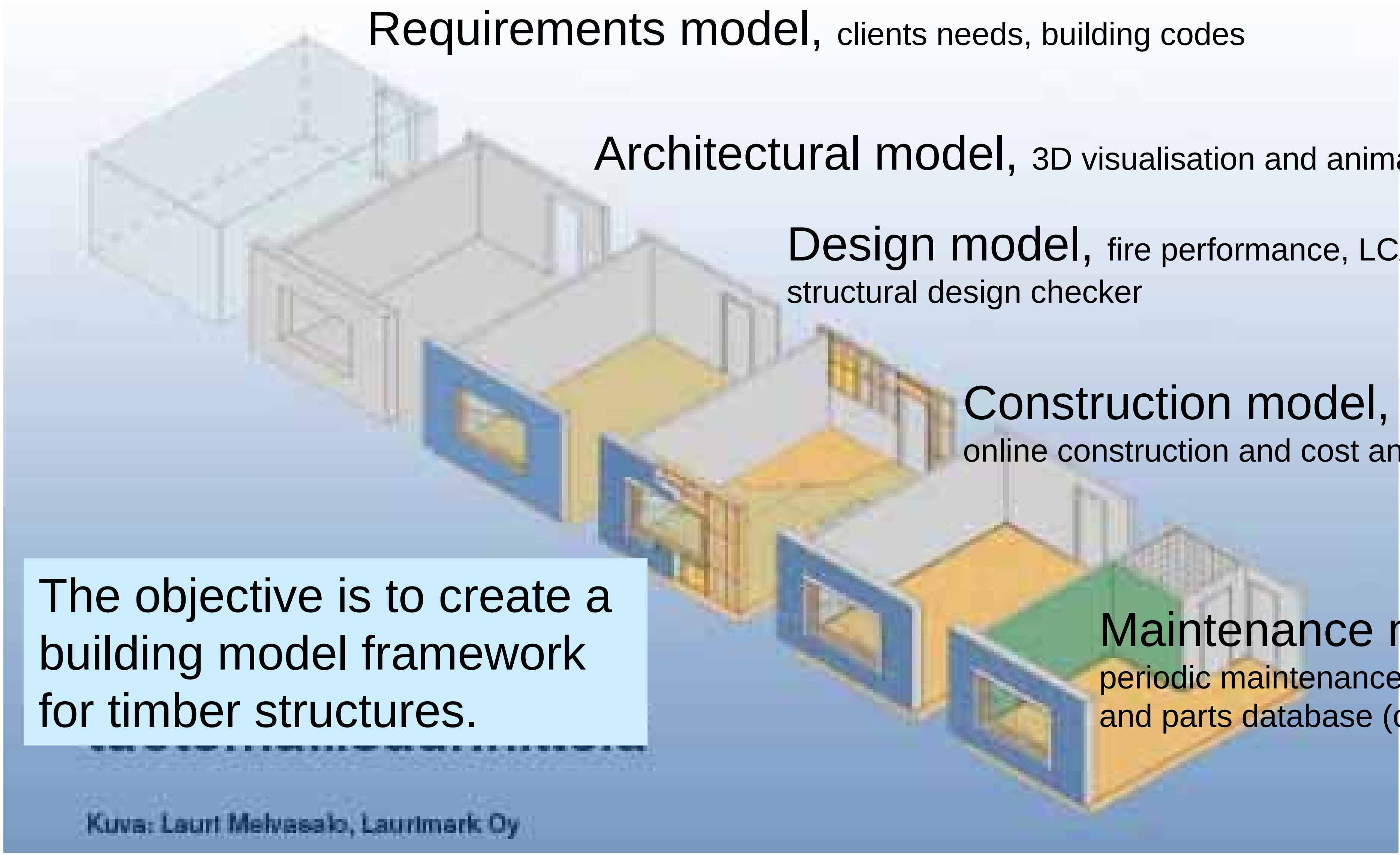

Requirements model, clients needs, building codes

Architectural model, 3D visualisation and animation

Design model, fire performance, LCA, structural design checker

Construction model, online construction and cost analysis

Maintenance model, periodic maintenance schemes and parts database (car ind.)

The objective is to create a building model framework for timber structures.

Utilization of Building Information Model in Timber Construction

Future objectives

- to develop an internationally recognized building information model adaptable for timber buildings,
- to produce a base catalogue – a building product and connection electronic database for ready-to-use applications (materials, details, properties: avoid design failures),
- to apply available and newly developed performance analysis (fire performance, service life performance) on timber buildings.

Cost E55 work in this development

To do:

- Evaluation report on the information needs of the timber building sector.
- Product database, manuals and guidelines, ready made models for products
- Connection database for large scale structures
- IFC specification extension needed for timber structural design