Integrated approach for development of automatic building application systems

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Abstract

Building applications / permissions are mandatory passing points from design to implement building construction. One important benefit from use of automatic building permission system is the possibility to check design solutions in advance, which might give a higher degree of predictability and reduced production time. BIM-based design systems (software and process) exist, and it is therefore a paradox that the number of solutions for automatic checking of building applications, complete or partial, is very limited. Specification of computable rules is a challenge. This paper argues for the need of increased integration between legal building authority, informatics and construction can enable a shift in development of regulations adapted for model checking. There are no clear terms for identifying different types of automatic model checking systems. A framework for classification of degree of automatic processing of building application systems is presented. A new Norwegian public project called "ByggNett" is presented to illustrate ideas for an automatic building applications system.

Keywords: Model checking, regulations, building permission, ontology, BIM

1. Introduction to the missing links

Building permission is a mandatory point for all building and construction projects. Considerable amount of resources are put into this manually process, both by the applicant and by the building authority. A digital automatic, or semi-automatic, building permission systems should give a simplification with more predictable result for the applicant and less effort by the authority. The interest for automatic solutions should therefore be high. All "stakeholders" notes the need for improvements in this field, however the guts to take part is hard to discover. The regulations (law, act, code, directive, and standards) are written for human / professional interpretation. Converting regulations into computable rules is therefore not a straight forward job. Use of function based regulations is an extra challenge. According to previous study by Hjelseth (2012a, b) is a well-defined procedure for transforming regulations into computable rules needed for valid and reliable results. Can a multidisciplinary approach contribute to improved interpretation and prepare for implementation of rules into BIM based model checking software?

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The regulations are at national level (in Norway), but the processing of the applications is at local level. This has both to do with the legislation, and with the economy model. The application fee is going to the local building authority and calculated at full cost coverage. This reduces economic incitements for improvement of the application process, and development of joint national wide project for a joint solution. Maybe the outcome of increased degree of automatic processing of building applications must be valued as more predictable results, (and increased activity in the industry) and more targeted regulations (regulations can be tested on a variety of models / buildings).

2. Development of systems for automatic checking of building applications

2.1 Need for an integrated view

The arguments for an integrated approach is based on a perspective of development from the single domain view of the legal, informatics and construction domain, through the double domain view and ending up with a triple domain view which focus at the interface between legal, informatics and construction. The integrated approach is illustrated in figure 1.

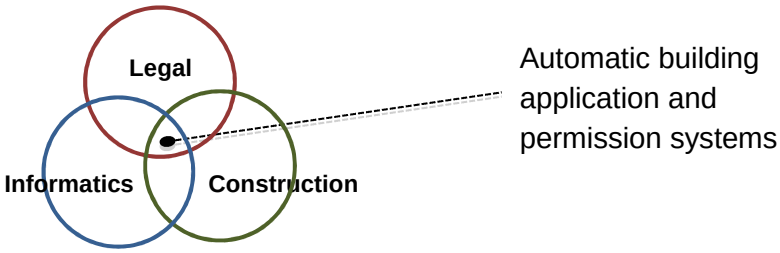


Figure 1: Model of integrated approach for automatic building permission systems

We start exploring these three domains by taking a single domain view and expand this to a double, and finally to the triple domain view of integration.

2.2 Single domain view

The three domains in the single model view model are:

- Legal specifications of regulations (regulations include: law, act, code, regulative, directives, standards etc.). Legal is a domain with long history and its own “language”. Legal have tradition for interpretations and references to other regulations for complete interpretation used in a single concrete case. Solving the discussion about “Performance based” versus “Prescriptive based” regulations is an important part of making regulations computable. Performance based specifications are known as “recipe” specifications, while prescriptive specifications are known as “end result” specifications (Gibson, 1982). BIM-based model checking software works with discrete metric. Prescriptive statements are therefore in principle prepared for implementation into BIM-based model checking software. Performance based specifications have quantitative goals or objectives. They are in principle much more interpretable, but might give better conditions for innovative new solutions

(Oleszkiewicz, 1994). Implementing this type of statements into model checking software is not a straight forward process.

- Informatics is a broad domain and often divided into two disciplines; the natural science based computer science and the organizational aspect from social science. The first domain is about “systems for how to exchange data” (syntactic / semantic interoperability). Use of standards from W3C such as Web Services, XML technology, and support for Sematic Web (W3C, 2012) and IFC and IFD (built on ISO standards) from buildingSMART (2012). The second domain is more focused on process and collaboration for “Systems for specification of information to exchange” (semantic / organisational interoperability). Use and IDM, Information Delivery Manuals (buildingSMART 2012) based ISO 29481-1 standard is an example of applicable specification of solution. Development of solutions can also be divided into three stages: 1) system design – 2) software programming 3) implementation. This paper focus on primary on system design.

- Construction includes architects, engineers, contractors, facility management (AEC/FM-industry). The industry is fragmented and the complexity and relations of work and information flow is hard to understand for outsiders. Process – and much of the information flow - is based on accumulated knowledge. Implementation rate of ICT is very low compared to heavy investment industries such as aerospace. The fragmented AEC/FMO industry is therefore very dependent on standards, both on legal issues like contracts and specifications system of product and works, as well as within ICT, where use of the ISO based IFC format is increasing.

2.3 Double domain view

As illustrated in figure 2 there are three well established research domains. But there is a lack of research projects, and research traditions, that covers the challenges regarding model checking of building applications. If we split the integrated figure 1 into double interactions, we find some established research approaches, illustrated in figure 2.

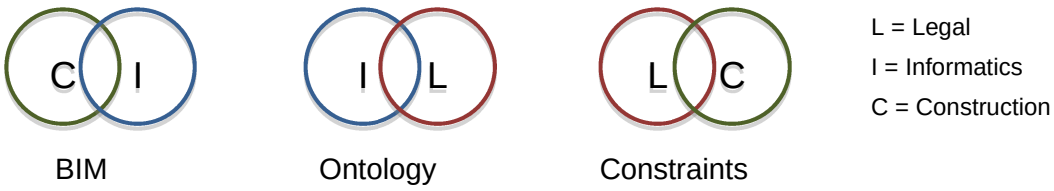


Figure 2: Combinations of interference between informatics, legal and construction

- BIM - building information modelling can be regarded as the crossover between informatics and construction. So far, the focus on “the I in the BIM” has been limited. Most focus is still on 3-D geometrical representation and visualisation. Agreement regarding delivery of information is not in practical use, despite that BuildingSMART has adopted the IDM standard (based on ISO 29481-1:2010) as one of its three “pillars” of BuildingSMART..

- Ontology: Regulations are based on text written in a way that often has to be interpreted. There is a challenge regarding function based and prescriptive regulations (IRCC, 2010).

Terms and definitions is not a part of the regulations (as with standards. Established practice makes interpretations more easy / predictable. Legal text is not structured for implementation into model checking software. The connection between regulations is also a challenge. Use and understanding of a term in one regulation is not necessary identical in another regulation, or can be identical under some conditions, but not all.

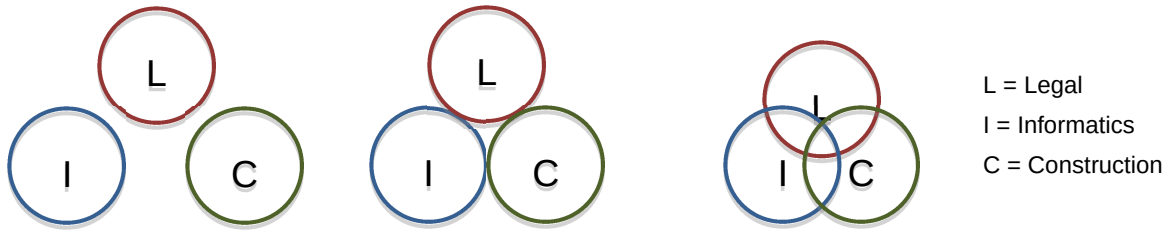
Understanding the impact support of tagging the text in regulations with RDF, (Resource Description Framework), (W3C, 2012) for strong semantics will be a large improvement for further system development. An example is the “Byggeregler på ett sted” (Regulations in one place) by the Norwegian Building Authority. This is a web-based archive with all relevant regulation, law, code, and guideline. This includes also previous versions, compared to paper based version, or finding the information by responsible authority, collecting and updated list of links is an improvement. However, compared with a RDF solution enabling search across all relevant documents, is the potential for further development very positive. Even if ISO offer standards in XML format, most standards are still only available in digital format as pdf-files. (ISO, 2012). ISO concept database is a collection of “Clause 3 - Terms and definitions” from all standards, but the concept database is not prepared or designed for advanced semantic search. However, when dealing with legal documents must the “doctrine of sources of law” perspective be included.

- Constraints: The legal regulations are determining what is mandatory to be included, or excluded, in a building project. This is done by defining requirement by putting up max or minimum values, including elements (such as elevators if the building is above a defined number of floors). This is defining constraints or framework for the design solution. Presumably it should be easy to understand, and implement, logical word by word, in a model checking system. However, this is not as easy as it looks like. The regulations are not clear about what information is needed. The definition of the metric in the regulations is often not clear enough – or open for definitions – or extremely detailed in millimetres. This can cause increased conflicts of interests between the political intentions of the regulations and what is realistic to conduct. Use of discretional assessment is a challenge – especially when the local authorities make their own assessments.

A classic situation is the inherited conflict between performance based and prescriptive based regulations. Identifying relevant metric is important when interpreting function based regulations into a model checking system which only process discrete metric. Studies by Hjelseth (2012a, b) and by Hjelseth & Nisbet (2010, 2011) indicate the defining metric from performance based regulations is solvable as “parametric” rules. The doctrine of sources of law must be taken into is relevant to give valid transformation of regulations into rules applicable for automatic BIM based model checking.

2.4 Triple view perspective; The integrated L+I+C model

The limitation with the double view can be reduced, or removed, by use of the triple view model which are focusing on the interactions between all three domains; Legal + Informatics + Construction. The L+I+C model are presented in figure 3. This model can be used to illustrate how large is the common domain for automatic checking of regulations.



Stage 1: No interaction
Stage 2: Some interaction, aware of each other's "situation", but no common domain
Stage 3: Further integration – common domain – Model / Rule checking is established

Figure 3: The L+I+C model for development of integrated triple domain view

The interaction between the three domains in practical / concrete situations does not have to be symmetrical, regarding number of "elements" between the domains. In many cases will the double view be the starting point, and supplement of the third domain does not result in a radical re-development of all domains. The new, third, domain will often works as a catalyst and trigger small changes with large impact.

An example of this is the previous example with function based regulations and defining of metrics. By use of informatics, it is practical to process an increased number of metric. Instead of using pre-accepted solution, it is possible to define a list of "characteristic properties" (the unique properties used when testing the pre-accepted solution). This does not imply a re-structure of the regulations itself, only a reference to the list of characteristic properties where they have used qualitative indicators. Processing would not be practical without an integrated view. List of characteristic properties would not be regarded as "simplification" in traditional human use of the regulations due to more text/specifications. The regulations have only to include a reference list of characteristic properties. Existing pre-accepted solutions can be used as a foundation for specification of characteristic properties. The informatics is just using its capacity to process large amount of discrete data. Model checking within this context can now be done with high degree of automatic processing with valid and reliable outcome.

3. Classification of degree of automatic processing of building application systems

Lack of harmonized terms for describing comparing solutions for automatic processing of building applications makes it hard to understand the content and purposes of different solutions, and to compare degree of automatic processing in different solutions. Table 1 presents a framework for classification. The taxonomy for classification is based on identifying degree of automatic collection of relevant information and degree of automatic assessment of the application.

Table 1: Framework for classification of degree of automatic processing in public building application systems

Level/ Term *)	Service: Automatic/ Manual	Applicant filling in	Input from other public registry	Submission system	Output to other public registry	Building authority Approval
0	Manual 100 % 0% / 100 %	Manual writing into paper forms	No input	Physical mail, hand-over	No output	Manual
1	20% / 80 %	All forms manual on computer	Registry managed by building authority	Transport by e-mail. Mail allowed	Information to other public authorities listed in application	Manual, but complete application checked automatic
2	40% / 60 %	Check that all forms are filled in	Business registry	Submission system with feedback of correct received Mail allowed	Digital transfer to some registry after manual control of quality	Pre-defined regulations done auto. Checklist on manual
3	60% / 40 %	Adapted forms, filling manually, some automatic transfer from other sources	Map / visualisation	Submission system with feedback of correct received Mail not allowed	Digital update of some registry. Manual /semi-automatic control of quality	Pre-defined regulations done auto. Report on regulation to be checked manual
4	80% / 20 %	Mostly automatic transfer from other sources / software systems	Geo related info like ownership of property. Regulations of site etc.	All information received digital by one system. High security. Mail not allowed	Geo reference of building. Ownership of property. Liability	Most regulations checked automatic. Manual overview and assessment of complicated reg.
5	100% / 0 % Automatic 100%	Automatic information from internal systems	Automatic from all registry	All digital received. Feedback on progress	Automatic to all registry	All computable regulation checked auto. Min. manual

***)** Terms related to each level:

0. Manual system
1. Form based submission system
2. Form validation system
3. Digital application system
4. Integrated digital application system
5. Integrated digital application and validation system

4. Development of technical solutions

4.1 Development of commercial solutions

Commercial software like Solibri Model Checker (use IFC-based, information rich) from Solibri Inc. in Finland (Solibri, 2012), and in some degree Navisworks (use several formats, but limited information) from Autodesk in USA (Navisworks, 2012) illustrate the potential in model checking. However, commercial solutions do not include rule-set of public regulations. This could be an option if the national building authorities developed and delivered detailed specifications (IDMs) for programming computable rule-sets. The commercial software developers could compete in offering customized services to their clients.

4.2 Overview of developed national public solutions

Digital solutions for processing building applications are not common service. Lack of common international terms makes it hard to discover potential solutions in other countries. The “CORENET” e-Submission System in Singapore is well known (CORENET, 2012). UK has developed the “Planning portal”; UK Government's online planning and building regulations resource for England and Wales (Planning Portal, 2012). Korea is developing the Seumter Code Checking System based on research at the Kyung-Hee University (Kim, 2012). This list is not comprehensive and the author appreciates feedback about other initiatives. Norwegian Building Authority has developed a “ByggSøk” (Building Application) opened in 2007. This is a web-based solution for verification of filled in forms related to specific types of applications. They plan to develop a more sophisticated solution called “ByggNett” (DIBK, 2012).

4.3 Development of public solutions for digital building applications in Norway

4.3.1 ByggSøk Norway

The internet based building submission system called “Byggsøk” was opened in July 1st 2003. The development lasted for three years and the cost was about 2 million Euro (2003 rate). With ByggSøk can the builder fill out the application and sent it via the internet. The level of service and complexity is illustrated in figure 4 (DiBK, 2012).

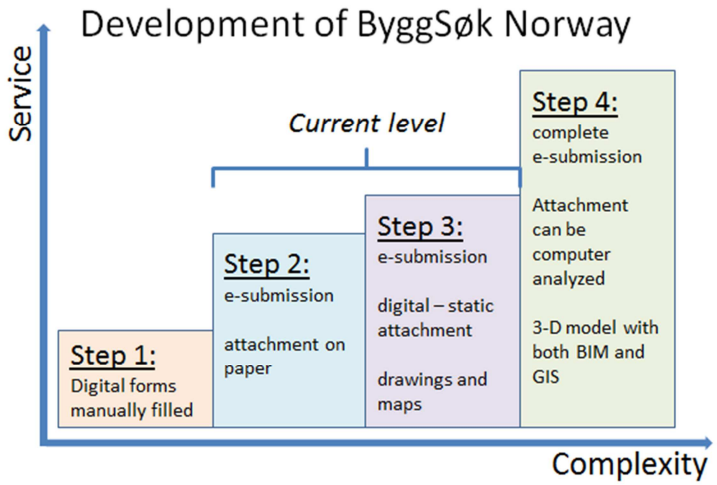


Figure 4: Development progress of the Norwegian ByggSøk solution (DIBK, 2012).

ByggSøk verifies that all required “fields” in the application forms are filled in before it can be submitted to the local building authority. Present version of ByggSøk cover step 3, but do also allow use on step 2. Step 2 in ByggSøk corresponds to Bew-Richards (2008) BIM Maturity Model (“the Wedge”) at level 1. Step 3 and 4 corresponds to level 2 on the Bew-Richards 0 to 3 scale.

In 2012 was approximately 110.000 applications submitted to the local building authority. Approx. 37% was submitted as paper-based forms (completed manually on paper, or as print-out of pdf-forms completed manually on the computer). ByggSøk was used as a tool for completing approx. 70.000 (63% of total) applications. The processing of all applications

submitted by ByggSøk is done at the local building authorities, in the same way as traditional applications based on paper forms. The application from ByggSøk can be submitted as:
1) printout on paper and sent by mail ordinary mail / delivered manually local building authority office. This enables supplement of paper drawings and other documents.
2) digital files by internet. The application forms as one single pdf-file, in addition to an XML structured file. Supplementary documents and drawings must be attachments as pdf-files. There is an option for submitting additional documents / drawing by mail. The processing does not start until the local building authority receives this.

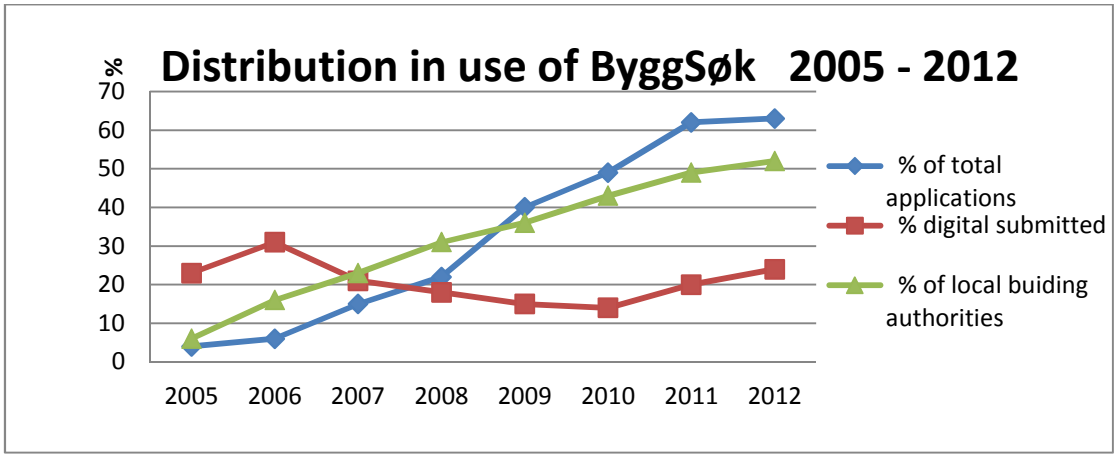


Figure 5: Distribution in use of ByggSøk 2005 - 2012 (DIBK, 2012).

Figure 5 illustrates an increase in use of ByggSøk as tool for preparing the application. However, the percentage of digital submission has not increased. The Norwegian Building Authority points out two perspectives as possible explanations:
- Applicant: Large number of documents from many sources has to be digitized. ByggSøk is only used to ensure that all relevant forms are filled in. No benefits (reduced fee, shorter processing time) for 100% digital applications. ByggSøk is used as an advanced "application writer" with input validation of fields in the form (but no validation of content).
- Local building authority: Lack of system to process the applications in a digitized way (XML-import and use of digital attachment). Received applications are printed out and processed manually.

4.3.2 ByggNett Norway

The Norwegian Government has in their white paper to the Parliament (St.meld. 28, 2012) given priority to the development of "ByggNett" (BuildNettwork) as a common platform for exchange of digital information in the AEC/FM-industry. The ambitions includes:
- further development ByggSøk into the new ByggNett framework for collaboration
- national registry for documentation of buildings
- integration of building information modelling (BIM)
- increased digitizing in general for all processes in the AEC/FM-industry
- integration of "Altinn" (extensive public Norwegian web-based solution for tax and business information)
- re-development of regulations (preparing for automatic model checking of projects)
- high focus on simplification (this is supported by a "Bygg enkelt" (Build simply) project.

Principles aligned with directives from the Norwegian Agency for Public Management and eGovernment (DIFI). They have proposed how joint national components should be managed, financed and developed. Common components or "building blocks" are defined as components in the IT solution that can be jointly used or reused in multiple IT solutions that allow the development of electronic services in the public sector. (DIFI, 2012).

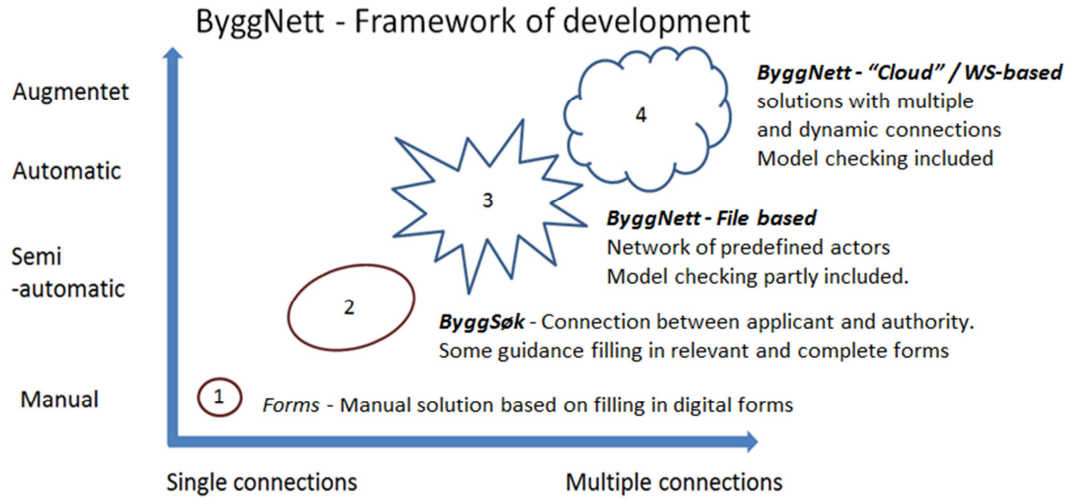


Figure 6: Possible development positions for future ByggNett solution

Figure 6 illustrates the dynamics in a possible development of the "ByggNett concept". Stage 3 represents a file-based approach where use of BIM models in IFC-format has a central role. Partly implemented model checking indicates that some parts of the regulations are not prepared for automatic (semi-automatic) checking. The information exchange is between predefined (known) actors. Stage 4 represent a "cloud" based solution based high degree of Web-Services. This requires well defined specifications of the information exchanged – so the receiver only get what's relevant. The following quote from the white paper to the Parliament (St.meld. 28, 2012) illustrates a pervasive approach for development of new and integrated solutions and services:

> ***"A scenario for the digital construction***
> *…..In the future, a builder could start with a digital model of the site with associated infrastructure that can be downloaded from the Internet. It automatically gathers information from many public and private registers (map data, property data, neighbour addresses, geological setting, the model of existing buildings etc.)*
> *…. With the aid of data from model, the builder considers alternative and environmental consequences, make live analyses and calculate costs. …*
> *….The digital model contains all the information needed for applying for a public permits and for a complete build process. The authorities have aligned building regulations so that the developer can check the model builder already from the sketch phase and throughout the modelling process.*
> *…. All relevant authorities interact on the same model.*
> *… When the building is finished, the public and private registry can be updated with relevant information from the model. In this way will the public have all necessary information about the building accessible for later needs….*"
>
> (St.meld. 28, 2012). Translation by author.

This states an ambition aiming complete digital information flow and pervasive use of digital solutions. The augmented perspective – to prepare for future needs – which will need more information about a large number of use cases. ByggNett will act as a role model of public government to take the leadership for digital collaborations processes in the AEC/FM industry – and public authorities involved the AEC/FM sector (DIBK, 2012).

4.4 Impact of model checking support

Use of model checking support can be regarded as a helpful tool and the catalyst for digitalization for the AEC/FM industry in general. The AEC/FM-industry is in most countries a highly regulated sector. In Norway a large number of public authorities can have an influence on the building application outcome. Examples of relevant authorities are: Labour Inspection Authority, Food Safety Authority, Directorate for Cultural Heritage and more. For the applicant is faster processing and lower fee of building application is of course relevant. But looking closer, this is most important in smaller projects were this has a higher ratios compared to design time and project cost. However, maybe the qualitative improvements resulting in more predictable outcome is the most important impact. The ability to use this as support during the design process can have significant impact on the design of buildings. Likewise can the national building authority use digitalization during development of new regulations and to explore consequences of new regulations and to identify interactions between different regulations. Internal survey at the Norwegian Building Authority (DIBK, 2012) regarding coordination about regulations for buildings in use pointed out that many regulations was overlapping, and could be collected in a single common regulation with just minor parts for each authority. The list of benefits of automatic assessment systems includes:

- Equal requirements for information for all local authorities
- Equal assessment for information for identical type of projects
- Digital information enables reuse for other purposes.
- Digital network of information
- Solutions for pre-check of application in advance of formal submission
- Support for design according to the regulations.

5. Discussion

The arguments in this paper for an integrated approach are based on principle and theoretical approach for an “ideal” solution. The empirical foundation in this paper is limited. A large number of legal and technical issues regarding development of digital solutions for automatic processing of building applications are not included in this study. This paper does therefore not give the full picture. The proposals in this study can therefore only be used as guidelines for development and further research.

6. Conclusion

The “L+I+C model” (legal + informatics + construction) explain the need of an integrated approach for development of automatic building permission systems. The L+I+C model clarify the interface between informatics, legal and building aspects and gives an overview of what can be applicable for automatic, semi-automatic or manual compliance checking. Support of automatic, or semi-automatic, building permission systems is assumed to give a simplification with more predictable result for the applicant and less effort by the authority.

Use of terms is often confusing, making it hard to understand content and functionality in application systems. To improve this situation a framework for classification of automatic / semi-automatic building permission systems been developed.

7. Further research

Further studies will focus on identifying countries and projects which develop and implement systems for processing of building applications. Analyses will include study of submission and validation / model checking systems and type and number for rules implemented. The author welcomes information about relevant projects and possibilities for collaboration.

8. Acknowledgement

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