BUILDING INTEGRITY
A PROTOTYPE FOR AN IT SUPPORT SYSTEM

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Abstract

The industrialization of the building industry requires a profound understanding of the interactions between building parts, elements, spaces and systems. The industrialization also causes an increasing number of actors and suppliers to be involved in the building process. The problems concerning interactions are not limited to technical issues. The organization of the process, as well as responsibilities and liabilities of consultants, subcontractors and other actors of the process contribute to the growing implications that constitute the problem in its whole. Neglecting the interaction problems could affect what has been called the Building Integrity problem, BI. The first part of the research has been concentrated to formulate the problem and the key questions to be answered. A conceptual schema describing the BI problem tentatively has been outlined. The schema includes some interesting classifying attributes, *e.g.* the functions of a building, building parts, spaces, actors and the causes of building defects. A so called "defect model" has been chosen as a base for an IT Support System. The system aims at supporting certain actors to detect BI problems in the building process. A prototype system is currently developed and is described.

1. INTRODUCTION

1.1 The Problem

Many of the problems causing poor effectiveness, low quality and increased costs in the building process depend on lacking coordination between the actors of the process, Appelqvist & Keijer [1994]. A typical case is a draining gutter in a bathroom, where not less than five different workers have to coordinate their jobs, figure 1. The case emphazes that the workers of the building process need good knowledge of the tasks of each other and that they must exchange information properly to have the entire job completed in the right way. In the case shown in the figure the coordination was insufficient and a *building defect* occurred. If the problem had been recognized in advance the task may have been completed without remedy.

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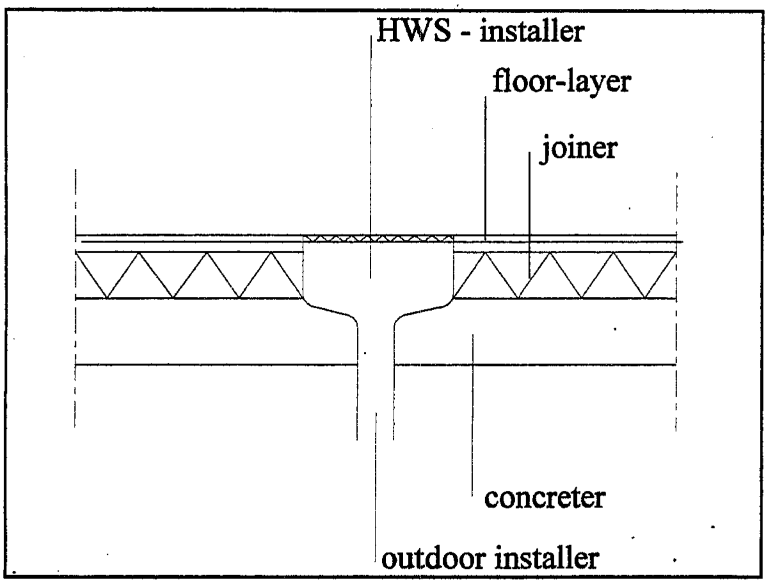

Figure 1. *Five different workers have to be coordinated in order to complete a draining gutter, Appelqvist & Keijer [1994].*

The number of problems met during the design and construction phases will be reduced if the actors of the building process have enough experience and sufficient knowledge of the common tasks to be achieved. As a result, the number of defects of the completed building will reduced. However, the variety of problems is immense. Similar tasks and situations are not recognized as such. Feed-back information very often is not treated on a generic level. For example, when an exchange of materials used in a wall has taken place the noise transmission problem, well handled with the original solution, reappears together with new material. Other situations can be more complex and may not so easily be recognized

The way the building process is organized also very much influences the emergence of various building defects. For example, use of (inexperienced) subcontractors instead of own work force invoke error-prone procedures requiring more experienced supervising personnel, who in turn may not be available to the required extent.

1.2 Building Integrity

The main idea behind Building Integrity, BI, is how to give the actors of the building process effective support for avoiding problems before they cause building defects. Some areas of specific interest could be pointed out as a framework for BI, Appelqvist & Keijer [1994], *viz.*

- the interactions between building systems, elements and components,

- the interactions between the actors of the building process, in general of different professions,
- the transfer of information from phase to phase of the building process.

It is rather easy to analyse a specific practical case like the one mentioned above, figure 1. A more general approach must, however, be applied for a BI support system. The help from the system can not only be based on exactly documented situations which had been reported in advance as problems. There will be a need for systemization including modelling and classification.

2. EARLIER STEPS OF THE RESEARCH

2.1 Identification of the BI problem

The starting point of the project was some 30 descriptions of building defects of different kinds, related to assumed BI problems which all incurred cost for remedy, Bertfelt & al [1992]. In an analysis of these defects it was recognized that they emerged at different phases of the building process and often depended on insufficient coordination between different actors of the process.

In this first step some classifying entities were defined, Keijer [1993], *viz.* building functions, physical connections, spaces, building phases, timing, metrics, and organization.

2.2 The Building Product Model and BI

A deep analysis has been done in the ongoing main study focusing on the choice of entities and the relationships between these entities. Related fields of Building Integrity, *i.e.* building defects, feed-back problems, the complexity of the building process are important part of the whole area of BI, Appelqvist & Keijer [1994].

For the general BI problem it is unsatisfactory to address only physical objects and interactions. It is equally important to have the these aspects included in an overall framework of the building process. The process and product models should be linked to each other, as suggested by different authors, *e.g.* Karstila & al. [1991].

Some principal interesting BI object classes and their relationships have been modelled in a tentative conceptual schema. They have been incorporated in a more general schema defining relationship both of the building product and of the building process. BI has a very close relationship to building product models. The schema tries to describe this fact. However, for the time being, the research is not directly based on this. BI is seen as a phenomenon of its own. Loose links to a more general view will be preserved. These aspects will be developed more thoroughly later.

2.3 A defect model and classification

As a base for classification a so called "defect model", DM, has been developed based on a model by Josephson [1994]. The model describes the generation, the detections and the propagations of building defects. A building defect can be seen as a chain starting with the cause of the defect, the actions of the actors involved, the manifestation of the defect and, finally, the consequences and the remedies of the defect.

A proposal for a classification based on the DM has been elaborated. Several reports building defects, *e.g.* Bonsor & Harrison [1982] and Bergström [1989], have been used to examine how defects normally are grouped in different tables based of some particular aspect. The tentative classification has been checked against the views of the reports and consequently modified. Table 1 shows the classification of *causes of defects.*

Class	**Cause** (often interpreted as)
1	Knowledge
2	Experience
3	Engagement
4	Communication
5	Coordination
6	Planning
7	Control
8	Externally generated defects
9	Process understanding
10	Other

Table 1. *Classification of causes of defects.*

Building defects generated outside the building process are *externally generated defects*. For instance, defect material supplied to a building impose a defect also to the building.

Defects can be invoked by actors due to lack of *process understanding* in relevant aspects, caused by lack of knowledge, experience or simply dedication to the task.

3. A PROTOTYPE FOR A SUPPORT SYSTEM

3.1 The purpose of a Support System

The main idea behind an IT support system is to bring down the number of building defects by offering the different actors help in their daily work. Problems concerning BI should be detected in time so that actors involved can coordinate, both, physically and functionally building parts, systems and performance.

The system must be easy to handle and to learn so it is used frequently also when a user suspects a problem or is uncertain about a situation. The system should procedure answers from questions based on a vocabulary adequate for the user of the system..

The purpose is also to give the users a tool for feed-back of experiences. The system should also function as a personal information system, as well as an information system for a team, a department, a building site or for the whole enterprise.

3.2 The user of the Support System

During the design phase a lot of information is created and distributed among the actors of the process. The final result is drawings and specifications which aims at describing the model so well that the building can be constructed according to the intentions from the design phase. From reports on building defects it is found that about half of the defects come from the design phase. An IT support system for the *design phase* could help actors to detect problems so that a *coordination* can be carried out in order to emphasize relevant BI information.

Another key user of a BI support system is the *purchasing function* of the construction phase. The planning and coordination of material should start already in this phase. The design information must be transferred to suppliers and subcontractors, but ideas, intentions and prescriptions are seldom completely documented and duly transferred. Mistakes in this part of the process are frequent.

Figure 2 indicates the interesting functions to be supported by a BI support system in this phase of the current research.

3.3 Planning for the prototype development

The job with the prototype for a Building Integrity Support System, BISS, was divided into four steps:

- modelling the BI problem and its close interrelationships to adjacent phenomena, *i.e.* Building Product and Building Process,
- elaborating the interface together with some end-users,
- designing the database,
- programming and testing.

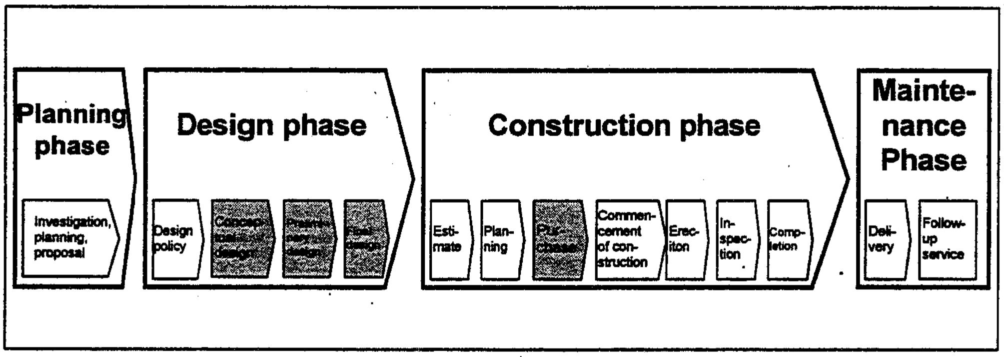

Figure 2. *The main actors in the building process. Shaded areas indicate the functions to be supported with a BI support system.*

A group of students from the Computer Science Dept. at the Royal Institute of Technology, Stockholm, was engaged in the project in order to contribute with their knowledge of IT and for the development of a first prototype for further testing and evaluation.

3.4 Modelling

A number of modelling seminars were carried out. The starting point for the modelling was the classifying entities described earlier. The model was adapted for a future expansion and to facilitate exchange of information from building products models.

The principal entities and their relationships derived from the modelling work are depicted in figure 3. The main entity (object) describes a Building Integrity defect or the information of such an entity, *BI defect/information.* The relationship between two entities is depicted by an arrow in the figure. The name inside the ellipse, *e.g. actor,* is the *class* name of that object class. An actor seen from the view of a BI defect is an *attribute (parameter)* characterizing the BI defect. The mapping *e.g. m,m,t,p* for the relation between BI defect and *cause* gives information about the relationships. The first component (m), *multivalued,* indicates that a specific BI defect can depend on one or more causes. If a relation not is multivalued it is *single valued* (1). The third component (t), *totality,* indicates that every BI defect has a relation to cause. The second (m) indicates that a cause can have a relation to one or more BI defects. The fourth component (p), *partiality,* describes that a cause could exist without a relation to any BI defect, Boman & al. [1993].

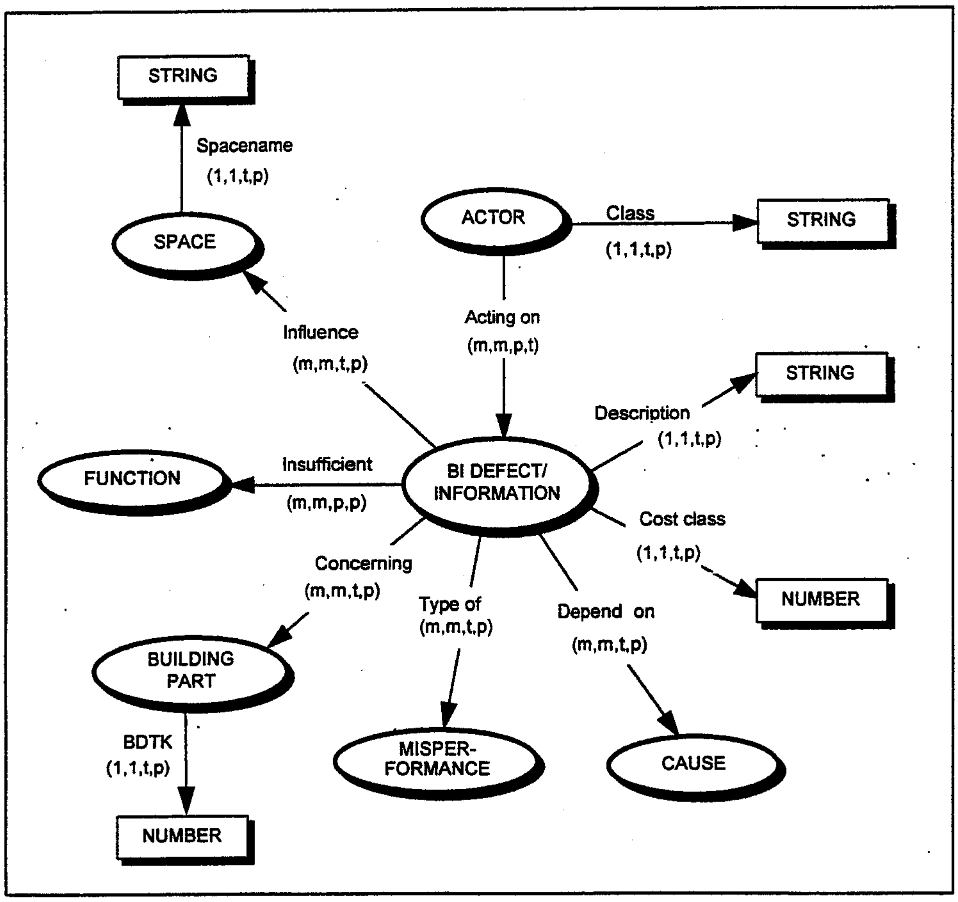

Figure 3. *A model for a prototype for a Building Integrity support system.*

The discussions with end-users indicated that the main point for the research project should be the user interface. Therefore the number of object classes was limited for the first prototype.

3.5 Software tools and hardware

The program must be easy to run in a an ordinary design office or on a building site. Many potential users of BISS use Excel and other Windows based programs. We think that it is important to give the possibility to switch easily between the different programs in the daily work and that the user interface for BISS should be very similar to other Windows applications. BISS must also allow handling many parameters and permit handling large amount of information in the database.

As the database tool Access and as the programming tool Visual Basic were chosen. BISS is adapted for Windows. The hardware should be an IBM compatible PC 486, 66 MHz and with at least 8 MB RAM.

3.6 User interface and the function of the program

The user interface was developed in a collaboration with a small number of potential end-users. It was important that all the work in the program could be handled from one main menu, figure 4. Another aspect was that it must be easy to select a parameter (attribute) from different classes without writing the word explicitly. The response from the program should include pictures and text.

A combination of parameters can be chosen both from the *same class* and also from *different classes*. The number of matching hits will be announced from the system. Are there too many hits, a discrimination can be achieved by picking one or more parameters. The answer from the system is presented in pictures, text and sound.

The prototype support six main classes: actor, function, cause, building part, space and misperformance. Building parts and spaces have a hierarchical structure.

A detailed searching in the system for a certain given situation can be achieved by the user. The possibility to get a matching answer for the special situation is weak. The hierarchical structure admit that a parameter in a higher level can be picked up instead and an answer can be given that describes a situation close to the problem in question. For example a problem concerning a door in an external wall is searched. However, the database contains a similar situation for a window. By using "hole in an external wall" as parameter instead of "door" the situation for the window can be found and may offer an answer with some relevant information to the problem in the first place.

There are two main modes for BISS, the searching mode and the updating mode. The system is easily switchable between languages; at present English and Swedish are available.

Updating information is to be acquired from practical cases, *e.g.* from documented building defects, from design problems or from own practical experiences from the building site.

3.7 Database

The database is designed based on the conceptual schema, figure 3. Every object class (building part space, cause, *etc.*) has its own relation (table). The

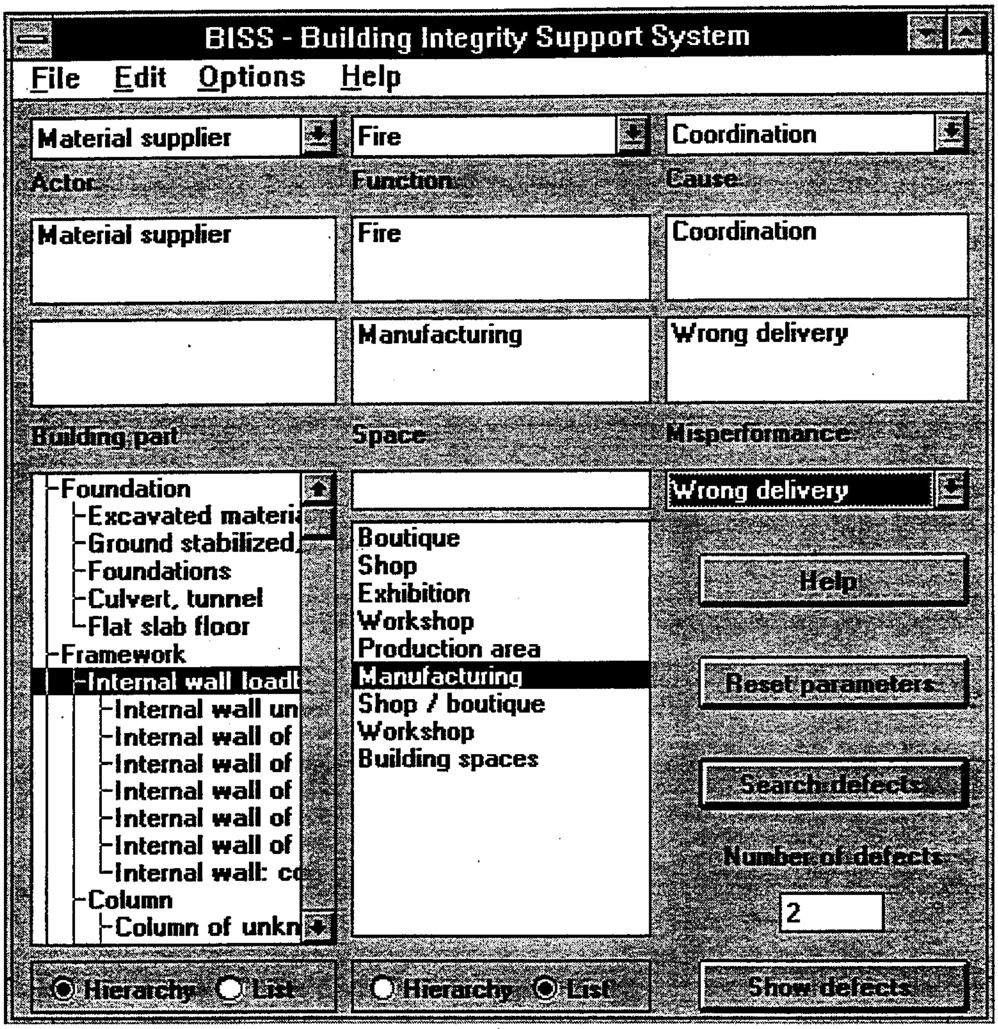

Figure 4. *The main menu for the prototype of BISS.*

multirelational condition m,m need another relational table. The interface for the database is based on SQL.

The prototype database continues about 20 tables. Three of the tables are shown in figure 5 as examples of the construction of the database. The primary keys are internal id numbers. The table *function* has three columns, function id, functions in English and in Swedish. The table *insufficient function* connects functions and *BI defect/information.* The table *BI_defect_information* contains text files, sound files and a cost attribute for each BI defect id.

Function

Function_id	English	Swedish
1	Stability	Stabilitet
2	Carrying capacity	Bärförmåga
3	Fire	Brand
4	Moisture, drainage	Fukt, avvattning
5	Air comfort	Luftkomfort
6	Air quality	Luftkvalitet

Insufficient function

Function_id	BI_defect_id	Description
2	31	Crack in the slab
2	32	
2	6	
4	8	Moisture damage
5	14	
8	13	

Bi_Defect_Information

BI_defec_id	Text_eng	Text_swe	Sound_en g	Sound_swe	Cost_class
4	e4.txt	s4.txt	e4.waw	s4.waw	-1000
5	e5.txt	s5.txt	e5.waw	s5.waw	-10000
6	e6.txt	s6.txt	e6.waw	s6.waw	-1000

Figure 5. *Three tables of the database.*

3.8 Testing BISS

Can BISS help actors solve problems and anticipate presumptive defects? A comprehensive test phase is the next step of the research with continuos improvement of the prototype. The test must be performed in a real project. Before starting the test the database will be completed with more practical cases which, relevantly increase the responses being expected for a number on situations. A tentative program for the test should contain, *inter alia,* the following questions:

- the layout for the menu,
- the choice of classes,
- used parameters,
- the hierarchical structure,
- presentation of the answers.

4. WORK IN PROGRESS AND CONCLUSIONS

The test of the prototype will probably indicate the need for further development and in which areas. The interface and the hierarchical structure of the database are two important part of the of the prototype to analyze and complete. Building defects will be documented continuously and classified in order to cover a broad scope of BI. New object classes will be examined in order to complete or exchange some of the present classes.

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