Analysis and Guidance in New Design Problems

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1. A new design problem: changes in Dutch secondary education

One of the main pitfalls of architecture has been the tendency to reduce design problems to stereotypes and resolve them by falling back to known solutions. Examples of this tendency are abundant in the history of architecture, e.g. in the rise of both Modernism and Post-modernism. Mindless repetition, theorization and sanitization of means and ends reduces designing to proscribed results or prescribed routes that may be acceptable within a small professional domain for short periods of time but ultimately fail to appeal to the users of the built environment and reduce the respectability and the scope of the profession. We should therefore be thankful to all new design problems that arise from wider social changes and treat these problems with interest and respect, without arbitrarily and summarily reducing them to solutions we already know. The invigoration of architecture and especially of its methods and techniques relies heavily on new challenges.

One such new design problem can be found in Dutch secondary education, which has been undergoing a fundamental change as a result of the combined force of new didactic approaches combined with social and technological developments. The education provided at the end of last century no longer met the demands of the times. Knowledge gets out of date quickly; professions change and employees switch jobs all the time. Lifelong learning and adaptation to new circumstances become conditions for which pupils must be prepared especially in secondary education. The new didactic approaches are based on new ideas of learning and teaching. In essence it is about shifting from amassing knowledge to obtaining skills.

The consequences for the accommodation of Dutch secondary education have been extensive and what complicates matters is that the requirements underlying the educational change and building modification are continuously changing. The original educational changes of the 1990s as described above were initiator of a wave of new approaches to teaching and learning, as well as to new organizational concepts. Many schools are exploring and adopting new, even experimental ideas in open-ended processes of change. Such ideas have spatial requirements that deviate even further from the conventional classroom arrangement, both in terms of individual workplaces and with respect to scheduling. Finally, the necessity to modify existing buildings has also been treated as an opportunity to accommodate and anticipate future demographic changes. These influence the size and the specialization or type of a school.

Our interest in this new design problem relates to design support and guidance (Steijns and Koutamanis 2004a, 2004b). As outlined in the paper "The Chair for Computational Design in 2000-2005" (a description of the framework of the research is presented in the previous Chapter), using computer technologies for facilitating design information management is an unobtrusive way of enrich design thinking with explicit and well-structured information, transparent and efficient communication and clear, well-founded analyses of form, behaviour and performance. Admittedly a better informed designer is not necessarily a better designer; however, we know of no other remedy for arbitrariness and conformism. It is worth noting that when confronted with the interpretation of the meaning of new problems clients and users of the built environment are keen on information and analysis and generally successful in motivating even reluctant designers to partake to an exploration of crucial details, alternative approaches and possible but unaccustomed solutions. Such explorations are also important for the evaluation of existing solutions that may serve as precedents or reference. In the case of school buildings the ongoing didactic and pedagogic changes are not the only problem: for quite some time now there have been complaints about e.g. the interior climate of classrooms or the efficiency and safety of pedestrian circulation. Still, new designs kept on reproducing the established patterns and forms thereby intensifying client / user dissatisfaction and making painfully explicit inadequacies in architectural design thinking.

2. **Programmatic analysis**

The spatial and functional requirements resulting from didactic changes in Dutch secondary education contrast sharply with the stock of existing school buildings. Most of these buildings are quite conventional in spatial terms and offer limited flexibility and transformability. Most schools therefore require extensive modifications not only when new didactic models are introduced but also in the future when these models will evolve and be refined both in theory and in practice. These modifications refer primarily to two spatial levels.

The first is local and concerns the workplaces of the students: instead of the conventional instructivist clustering around teachers in relatively large and passive groups, most new didactic approaches attempt to empower the individual student. In practical terms it means that emphasis is on the learning environment of a single student, including the possibilities for flexible transformation of individual workplaces into areas for small groups (with or without a teacher).

The second level concerns global patterns and configurations: with the emphasis on the individual and the abandonment of fixed clustering on the basis of subject matter or age / learning level, the global organization of a school building becomes less deterministic. Student movements are more intricate and variable, while the allocation of activities and users to different parts of a building is less subject to top-down regulation.

The resulting requirements for efficiency, social cohesion, acoustics, flexibility (including adaptability and transformability), security and safety are extensive and complex. Designing new school buildings and changing the existing stock ask for flexible and creative strategies which take the new demands into consideration and facilitate comparison of these demands with designs and buildings at various abstraction levels.

The first component of these new strategies is a coherent, consistent and complete description of the activities that take place in the building and of the general and specific requirements on the accommodation of these activities. In conventional briefs programmatic requirements are usually distributed into a number of complementary documents that specify behaviour and performance from different viewpoints relating to different aspects or disciplines. The modularity of conventional briefs allows for omissions, vagueness and even conflicts between different aspects. The first step towards the correlation of these aspects is a complete enumeration of stated and implicit requirements using the list of activities as a backbone.

The many and often complex activities that take place in a school building are variable in many respects, from the participants to these activities to the time and place where they occur. The new didactic approaches intensify this variability by creating more overlaps in functionality and localization. Consequently, the clustering of activities into larger groups should be flexible and adaptable. The resulting clusters should allow the analysis of programmatic problems at a higher abstraction level and support the recognition and treatment of wider issues (i.e. pertaining to larger parts or aspects of the design). This means that changes in clustering could be triggered by any party involved in the design process, including the clients and users of the school. In order to allow for changes in the primary clustering criteria (e.g. from user group to activity sort to building service type or intensity) as well as for cascades of secondary and tertiary criteria that refine and test the top-level clustering, we have implemented the brief in a relational database.

The brief database is modular, comprising a number of interconnected files. Each module contains a particular class of requirements (spatial, functional, environmental etc.) and represents a particular aspect or viewpoint of a discipline (i.e. sources and custodians of information). The connections between modules operate on the basis of individual activities. This does not imply that each module deals with each individual activity. Environmental requirements, for example, refer to types of activities, while floor area requirements relate to different classes of activities. In all cases, however, it is possible to present the complete set of specifications for a particular activity, as well as for collections of activities that share common characteristics (e.g. users, facilities or functional requirements) but may also be arbitrarily defined (e.g. a part of the building). This allows for the evaluation of consistency (i.e. that all aspects and activities are similarly specified), completeness (i.e. that all aspects are present and that all groups and clusters are similarly composed and equipped) and integration (i.e. that the specifications of different aspects are correlated and compatible or commensurate).

The choice of individual activities as the backbone of the brief database derives from an atomistic approach that allows for bottom-up abstraction and direct correspondence between design entities (e.g. spaces, building elements or wings) with programmatic requirements. These are important for continuity throughout the design process and make the brief an integral part of a responsive informational background for all actions and transactions concerning the design, evaluation and use of the built environment. The utility of the brief database can extend beyond designing, as the programmatic requirements of an activity underlie the facilities management of the space that accommodates it. In the particular case of schools, programmatic requirements and the possible clusters that emerge in the brief are also closely related to the scheduling of teaching and learning activities.

3. **Building and stock analysis**

The integral brief used in programmatic analysis is one of the two main components of the design information system we have developed (demand). The second component (supply) consists of representations that describe a building or design and can be used for the analysis of formal and functional aspects (also with reference to the brief). Representations are structured and coherent descriptions of architectural designs. The goal is that each representation offers a complete and consistent reproduction of a number of specific aspects. The use of structured representations offers not only clarity and efficiency in the information registration and processing but also the possibility to quantify and computerize analysis. The information of every space and building element are not just interconnected, but also linked to external information. This makes it possible to automatically compare different data.

Geometric representation

The main difference between our geometric representation and conventional floor plans lies in that each relevant entity, i.e. spatial or building element, is described uniquely by a single graphic object. This allows us to measure properties in relation to behaviour and performance (for example floor area, volume, daylighting or building cost). Each entity is annotated with reference to external information, such as the activities accommodated in a space or safety requirements. In most cases these annotations refer to other modules of the information system (Koutamanis 2003). For example, programmatic requirements are annotated to spaces through links to the brief database (described later in this paper). This makes it possible to compare for example the actual area allocated to an activity with the desired one but also to analyse complex patterns relating to global performance such as routing (Koutamanis, van Leusen and Mitossi 2001).

A small set of primary properties forms the basis for the classification of spatial and building entities into fundamental categories. These categories describe the major subdivisions of design entities, such as the load-bearing vertical elements on a specific floor level or spaces for teaching languages in a particular wing. Following the constraints of the two-dimensional representational basis, the floor levels form the initial classification property. The categories are implemented with elementary mechanisms that can be found in all CAAD systems, chiefly layers.

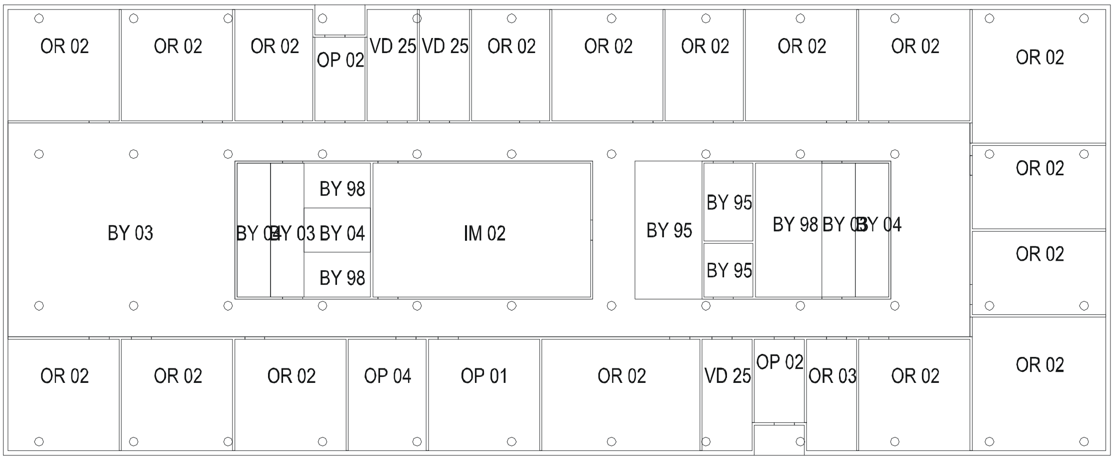

Figure 1: Geometric representation (Johan de Witt College, The Hague) (Meijer and Drimmelen 1994).

Other properties as well as most relationships between entities are implicit in the representation. These are recognized automatically only if and when needed. For example, normative evaluations of daylighting refer to the ratio of the floor area of a space to the vertical area of its openings that give on to the outside. In order to perform such evaluations, the external openings of a space are identified automatically on the basis of adjacency, measured and compared to the area of the space. The recognized relationships are explicit in evaluation reports but may also be recorded in the representation as semi-permanent properties (subject to dynamic change), especially if the recognition is cumbersome or time-consuming.

Topological representation

The topological representation is complementary to the geometric one. By representing entities and relationships in a graph it is possible to describe explicitly relationships and patterns in the spatial and building structure. Our topological representation focuses on the spatial entities and access between them as the main relationship. The resulting access graph (Steadman 1983) forms a basis for the description and analysis of spatial articulation at a higher abstraction level, as well as of dynamic aspects such as pedestrian circulation (Koutamanis and Mitossi 1993).

Of particular importance to our work is the ability to recognize the topological structure of building types. The conventional types (corridor, hall and pavilion schools) have a clear topological basis, even though their topology is seldom described explicitly. By making it explicit we are able to study relationships between types (including the transition from one type to another) and identify the type of a building not only in whole but also in part. The latter is crucial for the study of transformation, as it helps identify typologically hybrid solutions and partial mismatches between accommodation proposals and the spatial articulation of a building.

The analytical power of the topological representation lies in its mathematical background, which facilitates transition from descriptive and qualitative statements to quantitative measurements. In addition, the abstraction of the topological level permits explicit and focused treatment of issues central to the programmatic, legal and other requirements on the building. The clarity of visualization in the topological representation also contributes to the transparent treatment of issues relating to for example type identification and analysis, matching of a design to a brief and interaction between users and the building.

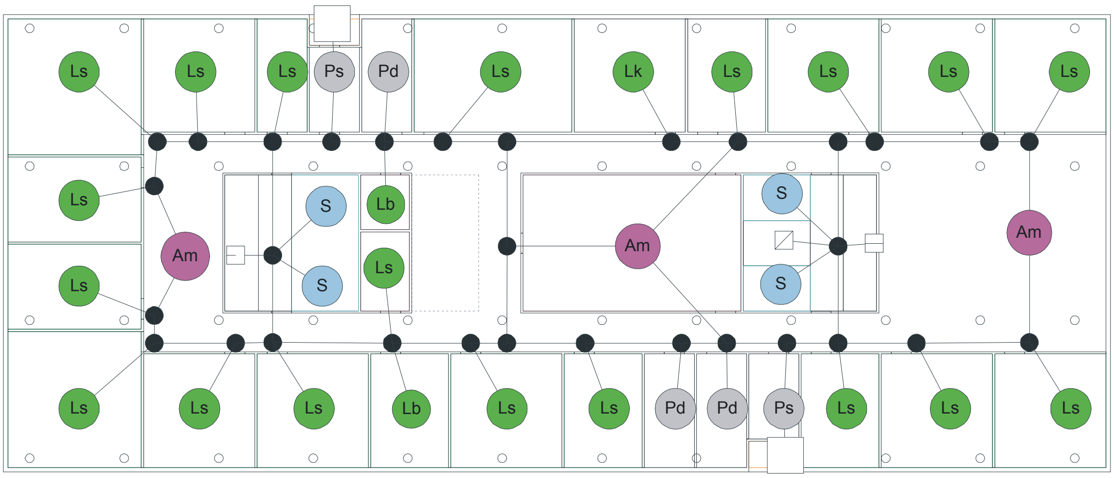

Figure 2: Topological representation of Johan de Witt College.

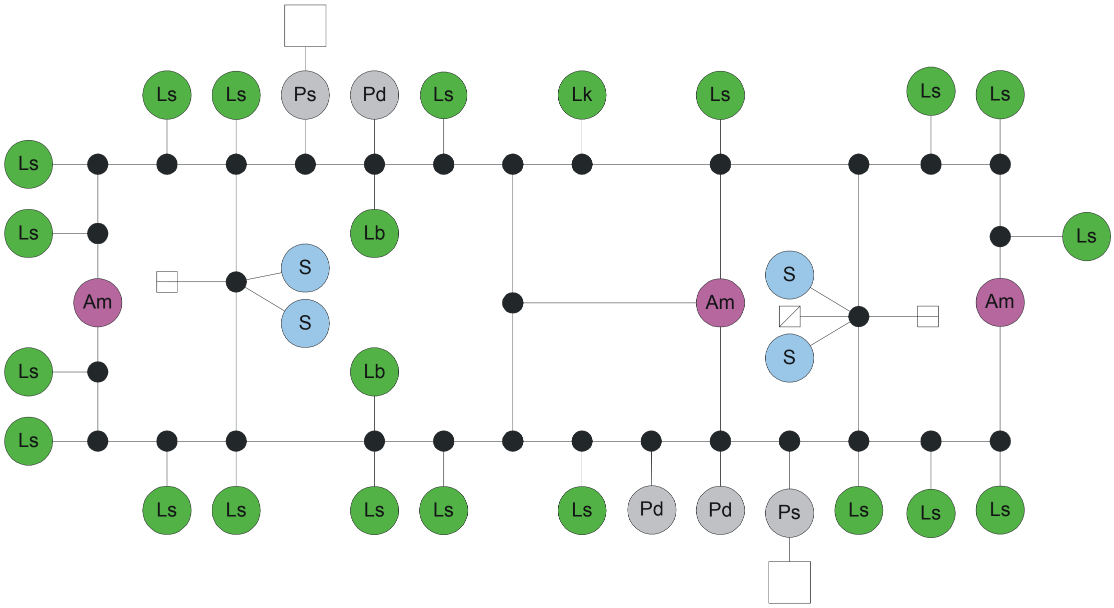

Figure 3: Normalized topological representation of Johan de Witt College.

Zoning

The acknowledged types for Dutch secondary education buildings (corridor, hall and pavilion types) are essentially topological, as they refer to the articulation of use spaces with respect to circulation structures and features. The geometry of spaces, structures and wings appears to play a secondary role in the definition of type. One could argue that the topological structure imposes constraints for the geometric development of a design. These constraints determine the suitability of geometric forms for a particular type. We believe however that the relationship between geometry and topology in a type is more intricate than mere deterministic, directed constraining. In order to study this relationship we employ the concept of zoning by which the building is subdivided into usually fuzzy and frequently overlapping parts with a readily identifiable formal, functional and performance character. This character derives from a combination of constraints, ranging from building structure and suitability to particular uses to geometric arrangement and circulation organization. The resulting zones integrate geometric, topological and functional characteristics into subdivisions of a building that frequently play a prominent role in a study of possible transformations.

In the case of Dutch secondary education school buildings we employ a basic zoning scheme consisting of three main type zones. The first is the *use zone*, consisting of spaces for the primary uses in the building. In school building this encompasses most classrooms, offices and study areas. The second type is the *circulation zone,* comprising both vertical and horizontal circulation facilities and spaces. The third one is the *service zone,* usually the most fixed part of the building with the least flexibility and adaptability. The circulation and use zones are normally more flexible and offer possibilities for transformation limited chiefly by the construction and external envelope of the building.

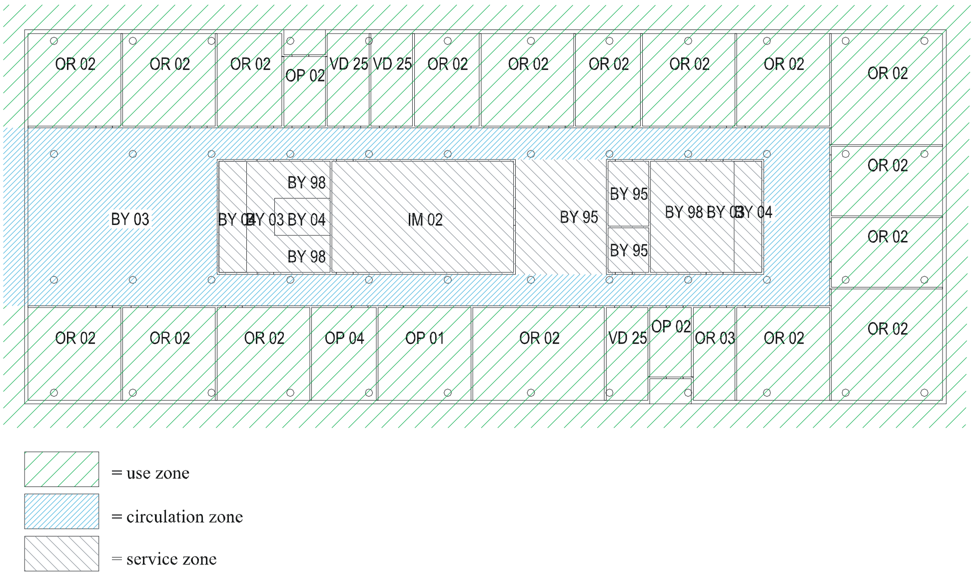

Figure 4: Zones in the Johan de Witt College.

The three zone types may be present in a building in a number of patterns that are closely linked to building type. For example, a three-zone pattern such as *use – circulation – service* is characteristic of the corridor type. A five-zone pattern such as *use – circulation – service – circulation – use* is common in buildings of the hall type.

4. Automating analysis

A primary advantage of structured representations is that they make explicit specific aspects of a building, thereby providing a sound foundation for automating design analysis. An example of this is the analysis of routing in pedestrian circulation – a main issue in school efficiency and safety. Mapping a route from A to B involves identifying the spaces that must be transgressed after leaving A so as to arrive at B. In our representation A and B are by definition spaces and the route that connects the two a sequence of other spaces and doors or other elements permitting human access. Such sequences are subgraphs of the topological representation (Figure 5).

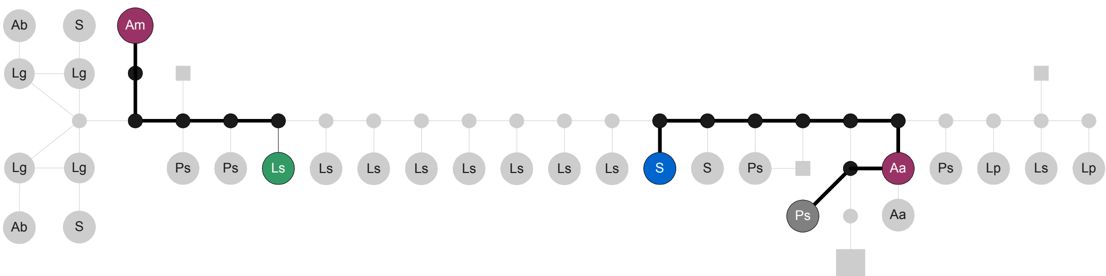

Figure 5: Routes in the topological representation.

The topological representation of a route connects the pedestrian circulation with the global spatial structure of the building. It offers a useful overview of all traffic patterns and the concentration of flows in critical parts of the circulation network. When more flows converge at the same corridor we can expect safety hazards, as well as possibilities for social interaction. This means that this corridor requires particular attention in the design and use of the building.

The depth of the topological representation (the number of nodes in the sub graph) is an indication of the complexity and psychological length of the route. Walking through a large number of connected spaces and doors to get from A to B mostly has a negative perception, even if the actual length of the route is relatively short.

The topological representation of a route can be automatically converted into a geometric one. This can be useful for example in analyses of fire safety. A direct comparison between entities in the geometric and topological representation means that every element in on representation is dynamically coupled to an element in the other: properties and patterns are translated from one representation to the other. This also applies to route patterns which are registered in the topological representation. The spaces and doors which are indicated by nodes and links of a route subgraph form the basis for the geometric description of the route (Figure 6). This description indicates the exact form of the route in space and can be used for the calculation of egress time in fire safety analyses (Koutamanis 1995; Koutamanis, van Leusen and Mitossi 2001).

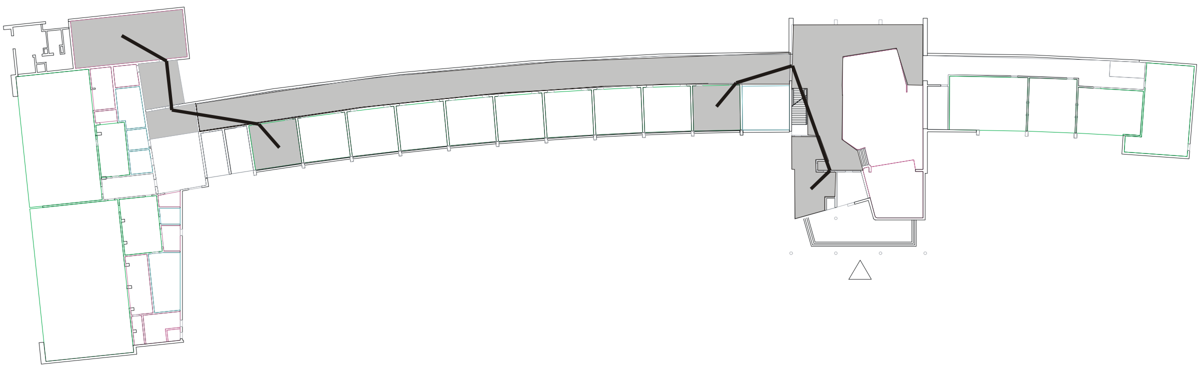

Figure 6: Routes in the geometric representation.

5. Topological representation of programmatic requirements

The topological representation of programmatic requirements is generated automatically from the brief database. Each activity and each (sub)cluster is defined by a node and each access relationship and the belongingness to a cluster is defined by a link between these nodes. This permits direct comparison between the brief with a floor plan both visually and mathematically. This comparison makes local and global problems explicit in the accommodation of a brief in a building.

The main difference with the topological representation of a building is that the topological representation of programmatic requirements does not normally contain circulation spaces. In the case of the building access graph these form the connecting tissue between the spaces. As a brief normally indicates circulation space as a mere percentage of the total floor area, the connecting tissue in the brief graph consists of abstract, cumulative objects that indicate the clustering relationship. This simplifies the matching of the graphs as it permits identification of subgraphs on the basis of stated clustering criteria.

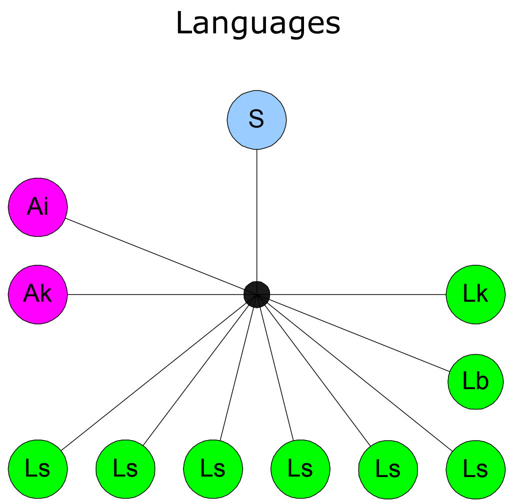

Figure 7: Topological representation of programmatic requirements for a cluster *(S = bathroom, Ls = classroom, Lb = storage, Lk = office, Ai = individual workspace, Ak = group work space).*

Each node in this representation is annotated by means of dynamic linking with the corresponding activity in the brief database where they become properties of the node. Changes in the brief database are automatically propagated to the topological representation either as changes to the properties or as structural rearrangements of the graph (re-clustering).

6. Design information management

The information systems and representations described so far represent independent modules that cater for specific aspects. Our assumption is that each module represents the subdomain of a particular discipline and can therefore be applied for the registration and communication of decisions taken by this discipline. By linking the different modules with each other we form a consistent system that makes possible the exploration of the total problem from all viewpoints. By means of the dynamic linking between the different modules the system remains automatically up to date and supports meaningful interaction between disciplines and aspects, including initiating analyses and suggesting alternatives.

An example of a basic analysis that involves more than one module of the system and which can be performed automatically is the analysis of floor areas, both in comparison with the brief and with respect to general rules and regulations (Mitossi and Koutamanis 1998). Such analyses may seem trivial but in reality they are time consuming and often very inaccurate, despite their significance for the design process: they form the basis for e.g. cost estimations and the departure for modifications of e.g. the circulation network of a building or underlying grids (if a design is judged to be extravagant or miserly in the allocation of space to particular activities). Information derived from the geometric representation and combined with the brief database or with external guidelines provides a fast, accurate and reliable floor area analysis at any moment in the design process and without any effort on the part of the users.

Table 1: Floor area analysis (comparison with brief).

Category	Number	Floor area	Brief	Difference
00_verb_klas	13	610,01	738	-127,99
00_verb_prac	0	0,00	0	0,00
00_verb_stud	0	0,00	0	0,00
00_verb_kant	6	56,00	65	-9,00
00_verb_tech	3	116,99	154	-37,01
00_verb_sani	5	157,56	174	-16,44
00_verk_gang	15	1083,75	1192	-108,25
00_verk_lift	10	1078,82	1402	-323,18
00_verk_trap	0	0,00	0	0,00
01_verb_klas	7	93,42	114	-20,58
01_verb_prac	13	743,49	1085	-341,51
01_verb_stud	0	0,00	0	0,00
01_verb_kant	0	0,00	0	0,00
01_verb_tech	10	214,81	255	-40,19
01_verb_sani	0	0,00	0	0,00
01_verb_berg	10	92,56	135	-42,44
01_verk_gang	7	53,72	70	-16,28
01_verk_lift	8	711,27	938	-226,73
01_verk_trap	0	0,00	0	0,00

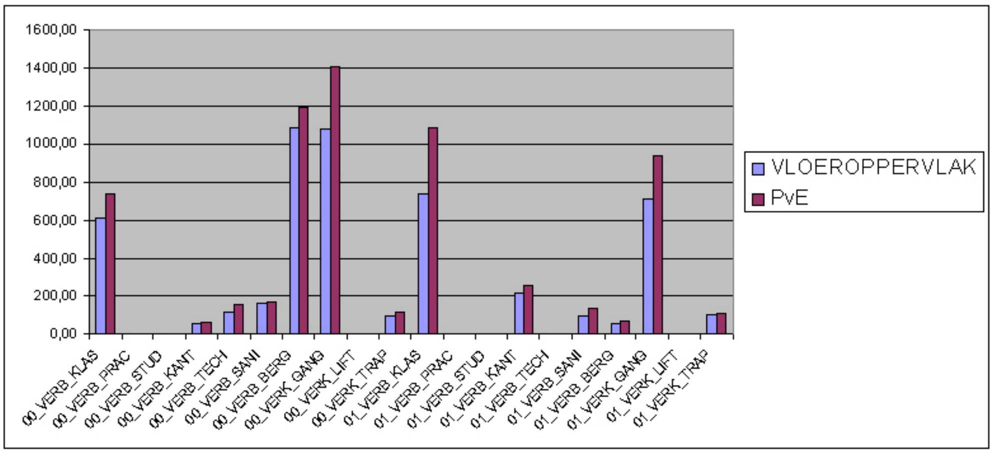

Figure 8: Floor area analysis (comparison with brief).

More advanced analyses relate to projected patterns of use. For example, every serious implementation of new didactic approaches inevitably challenges the way such patterns are regulated by hourly time schedules in conventional schools. The hourly basis is frequently abandoned in favour of longer periods that can extend up to two months. The exploration of the spatial possibilities and consequences of different types of schedules can be supported by the combination of programmatic information with the topological representation of the building. This representation is suitable for the representation and evaluation of static and dynamic patterns, i.e. the allocation of activities to spaces and the communication and traffic patterns that emerge as students and teachers move from one space to the other. Static effects are directly visible when the topological representation is annotated with relevant information from the brief (Figure 9).

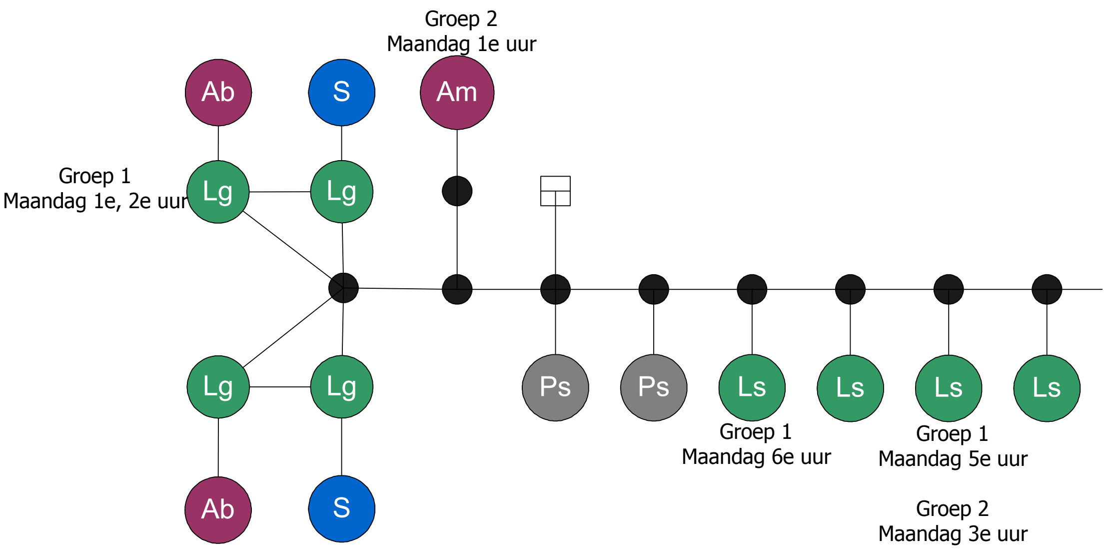

Figure 9: Scheduling in the topological representation.

This depiction of activity allocation can indicate a single time unit (hour, day, week) for one group of users (specific teachers or students) or cumulative (all users and all activities in a single time unit or all activities of one group for a longer period). This makes it possible to visualize and measure both the occupancy of the different spaces and the spread of activities. The subgraphs that depict the activities of a specific user group also form the basis for the analysis of dynamic circulation patterns. These patterns may refer to a particular movement (Figure 10) or to a cumulative representation over a period of time for one or more user groups (Figure 11).

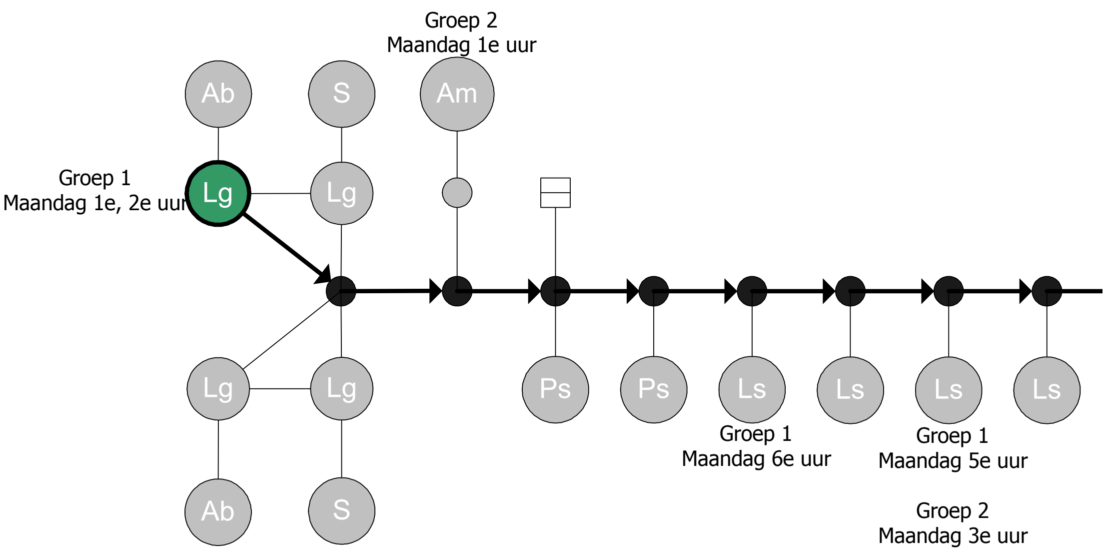

Figure 10: Traffic pattern of one user group in the topological representation.

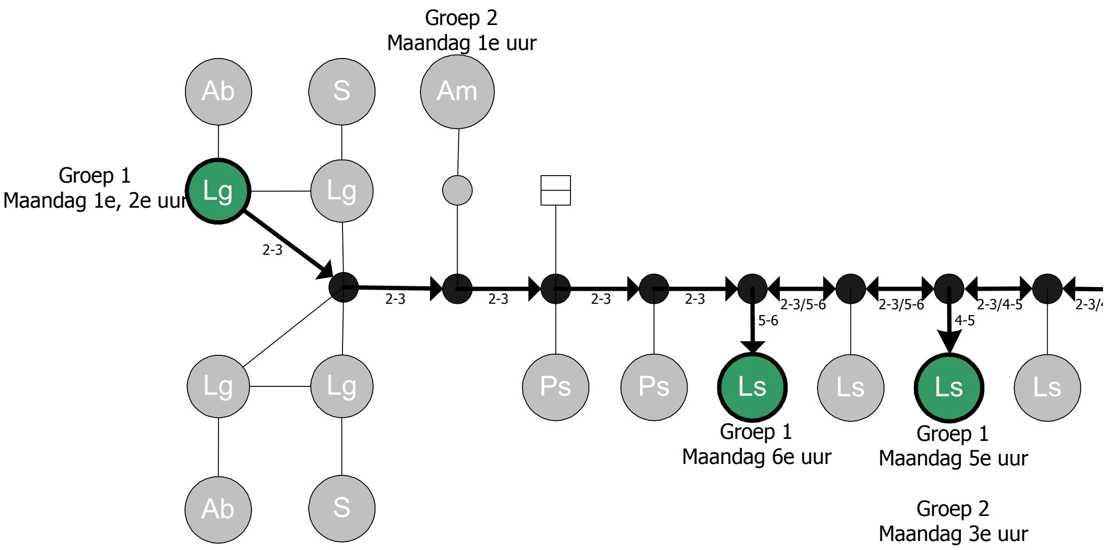

Figure 11: Cumulative image of the schedule of one user group.

Such analyses enrich the programmatic and design stages with the ability to make reliable projections of behaviour and performance and refine a design accordingly. Arguably more significant is that they are co-productions of different modules and hence common explorations of at least several parties that take part in a design process. In our system each party retains its self-sufficiency and responsibility for a part of aspect of the design, but at the same time it is offered connectivity to the others and through this the possibility of a global view of the design problem. This may not be high among the priorities in a common, predictable problem, but having to deal with a new problem with unknown or uncertain outcomes is generally seen as a valid reason for investing in the additional effort and organization.

7. Continuity

The educational system is continuously changing and a school building will have to anticipate all the time. By dynamically linking the integral brief to the building representation we can anticipate future didactic or logistic changes. This ensures continuity of demand-to-supply matching throughout the lifecycle of the building, including facility management, scheduling and minor or local building adaptations. The permanent focus of continuity is the registration of building behaviour and performance and re-evaluation of principles and solutions. The corollaries of that include:

- A better understanding of the effects of design decisions at many abstraction levels: evaluation of the accommodation of activities in a space reflects on the form of the space, its energy and climatic performance, the form and positioning of critical elements such as doors and windows, finishing (e.g. for acoustics and maintenance), the structure of the building (e.g. with respect to adaptability), etc.
- The ability to improve a building incrementally through either planned interventions or self-regulation: being able to discern differences between the projected and the actual behaviour and performance, to identify possible causes and test scenarios for the solution of problems makes designing and building permanent, dynamic activities.

- The necessity to maintain and augment information from the design process throughout the lifecycle of a building: information used in the brief and the design process re-emerges later not only in construction but also in the use of the building. We can understand better why and how a problem emerges in use if we keep trace of how relevant programmatic requirements evolved during the lifecycle and how correspond design decisions were made, implemented and finally understood by the users. Reversely and in true cyclic fashion, collecting and evaluating information on the relationship between user requirements and a building is a main source of knowledge for briefing and designing.
- The tools used for managing information remain essentially unchanged throughout the lifecycle: for example, the way we integrate information in briefing and connected with a design is also applicable to the correlation between user requirements and resources in facility management.

8. Discussion

Using design information management as a vehicle for design analysis and guidance is a powerful yet unobtrusive manner of promoting communication and integration, making issues explicit, utilizing participation and supporting continuity. The main prerequisites are two. The first relates to the main participants such as the architect and the client: commitment to developing, using and maintaining extensive interconnected information systems should be coupled to clear incentives and substantial benefits. This often means that the design problem should have a degree of complexity and difficulty that makes stereotypical solutions and processes less attractive as an easy way out. The second prerequisite relates to the tools and the underlying approach: proscriptive and prescriptive techniques which rely on acceptance of a frequently alien way of thinking and working offer little common ground with the interests and habits of the users and few guarantees for adequate performance beyond a generally small scope. Descriptive approaches fare better, provided they are effective in delivering insightful and comprehensive analyses of design information. Similarly, the tools that support information management should build on a thorough understanding of conventional processes and representations that allows us to retain their strong points, as well as identify and justify the introduction of new elements that improve on the weak points.