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INTEGRAL PLANNING – POTENTIALS AND CHALLENGES FOR THE CONSTRUCTION OF TIMBER BUILDINGS. A TEACHING EXAMPLE

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Abstract. The term “integral planning” describes the creative cooperation of experts from different disciplines with the aim of solving a complex, technical planning task. By involving all the disciplines and stakeholders at an early stage it is possible to achieve better solutions than in a linear planning process in which one designer directs the specifications to the respective specialist planners, who then add the corresponding engineering services. In the course “Integral Planning”, students from the fields “Architecture – Green Building” and “Civil Engineering – Construction Management” are working on a project in an interdisciplinary exchange over two semesters. Through the simultaneous interweaving of their specific skills, combined with a very free working method, the students are taught integral planning in a realistic setting with the aim to design a modular timber building system for temporary educational buildings according to the “cradle to cradle” principle.

Keywords: Integral planning, sustainable architecture, teaching architecture, teaching sustainability, modular timber construction, timber building.

1. Introduction

The word “integral” is borrowed from the Latin word “integer” and can be translated as “intact”, “complete” or “healthy”. In the broadest sense, “integral” also means “functional”. In the context of planning, the adjective “integral” can be seen as the understanding that complex systems are only working flawlessly when all sub-components of the system are functioning well. In this way, integral planning is a holistic approach of complex planning tasks [1]. Buildings have become extremely complex systems, where sustainability plays a fundamental role. Developers demand resilient buildings and the statutory requirements for energy efficiency are also continuing to rise. As a result, planners have to deal with the assessment of the entire life cycle of a building, from construction to deconstruction [2].

This growing complexity requires an interdisciplinary approach, and therefore, a change from a linear planning process to one in which experts and stakeholders communicate with each other on an equal footing. Integral planning is a life-cycle-oriented, holistic approach in which all planning participants and stakeholders are involved in an early stage of the project. Through the simultaneous involvement of all disciplines such as architecture, structural engineering, technical building equipment, users and facility management, the project can be grasped in its entirety and the necessary arrangements for optimal use can be made (Figure 1). Decisions taken in an early planning phase, play an essential role for the construction costs and the later life cycle costs [3].

Especially in the field of prefabricated timber buildings, where specific expertise is required, rather than for buildings made of brick or concrete, it is fundamental to involve all stakeholders in the planning at an early stage in order to set impulses, simplify processes and optimize the building design.

2. Theoretical Framework

2.1. Effects of integral Planning

The early involvement of the key players and specialist planners has far-reaching consequences on the life-cycle of a building. Buildings are responsible for about 40 % of total energy consumption in the EU and for about 30 % of CO_2 emissions. Furthermore, about 40–50 % of the resource consumption is due to building design and construction. Economic considerations and not at least due to the new EU taxonomy regulation, there has to be a change from a linear planning process to a forward-looking approach of a life-cycle-oriented, holistic view on the project. The planning strategies in the early process phases (strategy, initiation, planning) are responsible for the whole life-cycle-oriented performance of a building. The possibility to optimize life cycle costs, consumption of resources and energy and essential parameters to allow a flexible use of the building are remarkably high in these phases. Therefore, all necessary and available information and requirements for the project, particularly from the use phase, should be considered at an early stage and at the beginning of the planning in order to optimize the subsequent operation of the property (Figure 2) [4, 5].

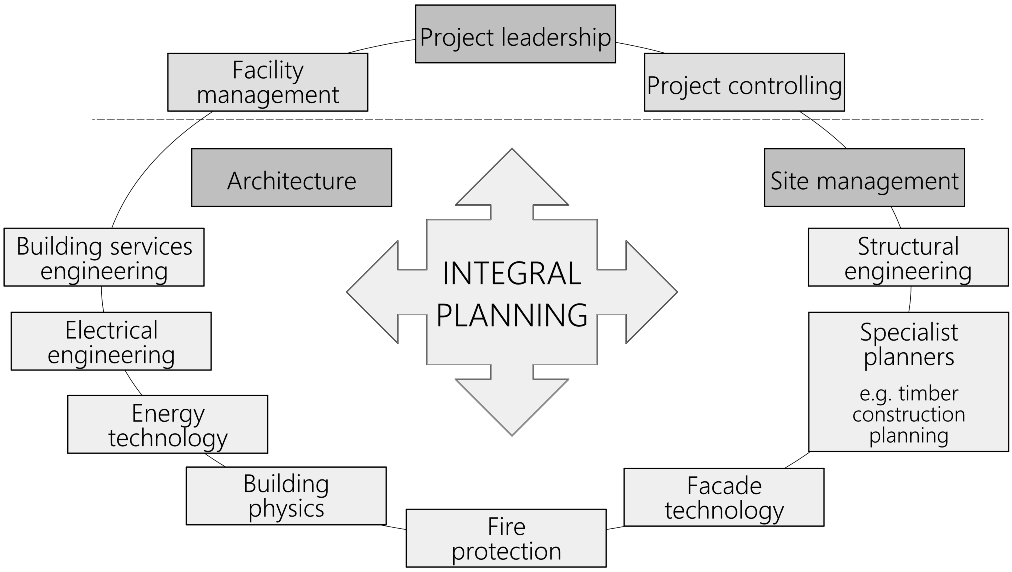


FIGURE 1. Integral Planning Team [3].

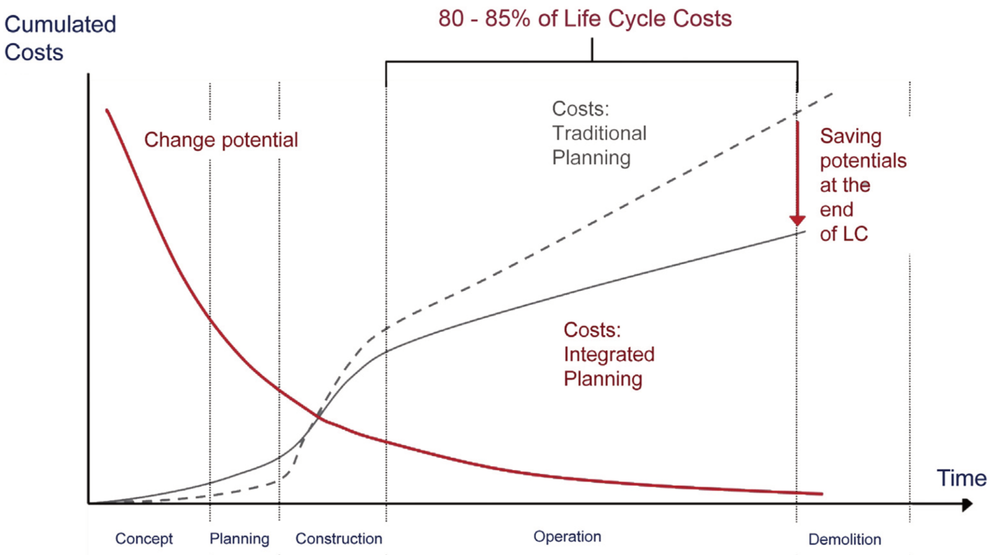
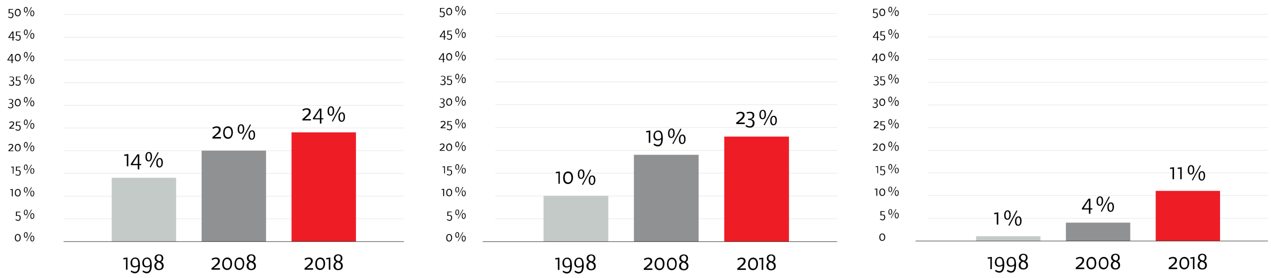


FIGURE 2. Cost development vs. change potential over building life cycle [5].

2.2. Integral Planning and timber constructions

In Austria timber construction has experienced a significant upswing in recent years [6] (Figure 3), but the collaboration of architects, structural engineers as well as specialist engineers and planners in the manner of conventional, linear planning does not work out properly for buildings with a high degree of prefabrication. It often turns out that the actors of the different disciplines are not sufficiently aware of the interfaces and the scope of services of the other planners in detail. The plan content and presentation depending on the maturity of a project is not uniformly defined across all disciplines. Specialist planners are often involved too late in the planning process, the team does not work synchronously and different planning depths prevent targeted cooperation. A lack of standards for digital data processing and data exchange puts an additional strain on cooperation [7]. Within traditional planning, details have to be revised frequently. Integral planning offers the possibility of dealing with characteristic features of timber construction at a very early stage in order to find superior solutions by permanent exchange of experience and knowledge [8]. It helps all parties involved to achieve greater clarity about the various interfaces in the project. Through regular exchange with experts, detailed questions can be solved at an early stage and the standards for digital cooperation can also be established from the beginning.

In order to prepare students for the growing trend in timber construction in Austria, specific trainings towards Integral Planning seem to be an adequate approach. In one interdisciplinary and compact course



(a). Total percentage of timber construction in Austria (by floor space).

(b). Percentege of residential houses made of timber in Austria (by floor space).

(c). Percentage of public buildings made of timber in Austria (by floor space).

Figure 3. Percentage of timber constructions in Austria [6].

	Recycling	**Environmental Impacts**	**Durability**
Building	Recyclability of individual components	LCA of buildings	Life span of buildings (depends on location, use, value)
Building Parts	Recyclability of individual component layers	LCA of building parts	Life span of building parts (exchange, location, quality)
Building Materials	Recyclability or reusability of building materials	LCA of building materials (EPD)	Life span of building materials (life span, function, location)

Table 1. Considerations of sustainable use of resources [9].

students learn to work collaboratively with specialist planners for their future careers, while they acquire specific expertise about contemporary timber construction. In addition, students learn to take a holistic view on their projects, a building's life cycle and life-cycle costs. When considering the life cycle of timber, it becomes essential the fact of keeping the building elements and component in use as long as possible. For this reason, the goal of the course's project is to develop design strategies for circular economy.

2.3. Life-Cycle of timber

Timber constructions have an excellent life cycle assessment (LCA) when locally produced. Dismantled wooden components can be recycled or even reused and, in this regard, timber is a long-term carbon storage [10]. When approaching holistically a new project, the sustainable use of resources is mandatory, wherein the following three points must be considered (Table 1):

- An efficient use of resources based on their specific properties and their potential of be reused and recycled.
- An in-depth analysis of their environmental impacts throughout the entire life cycle.
- An adequate design that maximizes the use of the building throughout time. That requires durability of the structure as well as flexibility in terms of floor plans and room height [9].

Conventional models for the cascade use of wood and wood-based materials focus predominantly on the material recycling of waste wood into wood-based materials and thermal recycling. In order to prolong carbon storage and save primary resources, it will be increasingly necessary to follow the higher-value principles of re-use and repair and to apply these increasingly in the construction industry. In the long term, building components should remain in the cycle before they are recycled or thermally recovered (Figure 4).

In particular, the recyclability of entire components and their layers is mostly an unsolved problem that still need to be assessed. The dismantling capability of a building must be considered in the very early planning phase of the project in order to ease a circular use of its components. Within the course "integral planning" the students were given the task of planning a circular timber building.

3. Method – design studio "Integral Planning"

The two-semester sequential design studio "Integral Planning" is a mandatory practical course for the student of the master programs "Architecture – Green Building" and "Civil Engineering" in the 2nd and 3rd semester. In this course students get in touch with different construction management processes and work out mechanisms for the design of communication

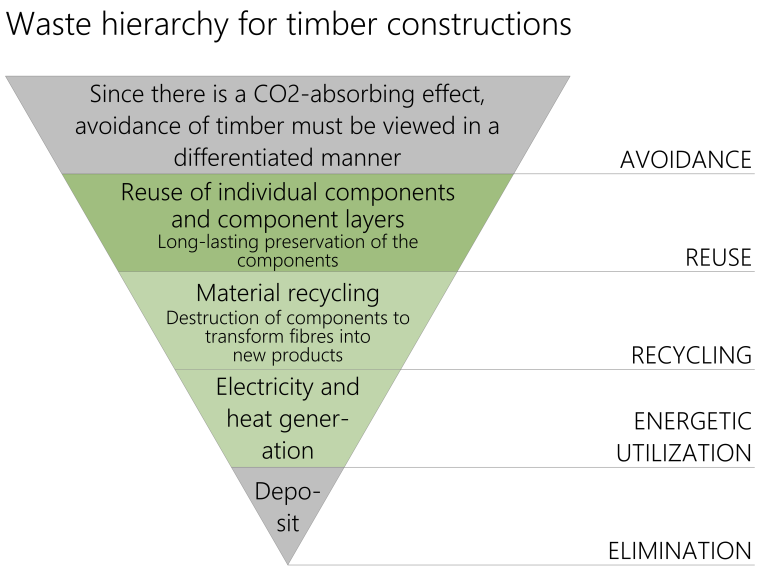


Figure 4. Timber waste hierarchy [11].

as well as for the distribution of responsibilities in practice. They work cooperatively to find technical and aesthetic solutions to given problems and optimize the interfaces until they jointly arrive at an ideal solution. Within the process, lecturers and experts take part as advisors in areas where specific expertise is needed, for example, detailed knowledge of timber construction and manufacturing processes.

The first part of the course (Integral Planning 1) took place in the summer semester of 2020 and the second course (Integral Planning 2) in the following winter semester. The course was attended by 75 students of the master program "Civil Engineering – Construction Management", who are subsequently referred to as civil engineers, and 22 students of the master program "Architecture – Green Building", who are referred to as architects. Thus, a total of 97 students participated, who were divided into 14 groups with a maximum of 7 members. Each group had at least 3 members covering the architectural tasks, where a team-leader was selected to be the contact person for the accompanying lectors in administrative and organizational matters. The following division was proposed for the tasks:

- Architectural design: Architects and designing civil engineers;
- Structural analysis and construction: Civil engineers;
- Building physics: Architects and civil engineers;
- Construction economics and project management: Architects and civil engineers.

A total amount of nine lecturers supervised the course, with one of the professors being responsible for the organization and coordination. The other lecturers supervised and advised on the above-mentioned areas.

3.1. Planning tasks

The students should find an aesthetically and technically elaborated sustainable solution to the following problem: *Architectural and structural planning as well as economic processing of a modular construction system for temporary educational buildings according to "cradle to cradle" principles.*

The building structures to be planned had to comply with the Vienna building regulations. The key challenge was to plan and construct the educational buildings in a modular timber construction, which can be dismantled or deconstructed into individual parts. The students had the task of developing a modular system from which classrooms and multifunctional rooms as well as sanitary units can be formed. These should be able to be combined to form a temporary educational building, while the different types of use had to be flexible and self-sufficient.

The aim of "Integral Planning 1" was the architectural respectively constructive design. In "Integral Planning 2", the project was continued, a submission plan was drawn up, the pre-structural and detailed structural analysis was calculated, and the implementation planning was drawn up for selected areas of the building. At the end, the project results were presented in groups to a high-ranking jury of internal and external experts. The result of one of these groups is presented in the next chapter.

4. Case study – group 13 "WOODUL"

Members: One female architect, four female and two male civil engineers.

The basic module on which the building is based measures 7.50 × 2.50 × 3.63 m. This ensured a room height of 3 m and also the possibility to move the

(a).

(b).

Figure 5. WOODUL – the module that can do everything [12].

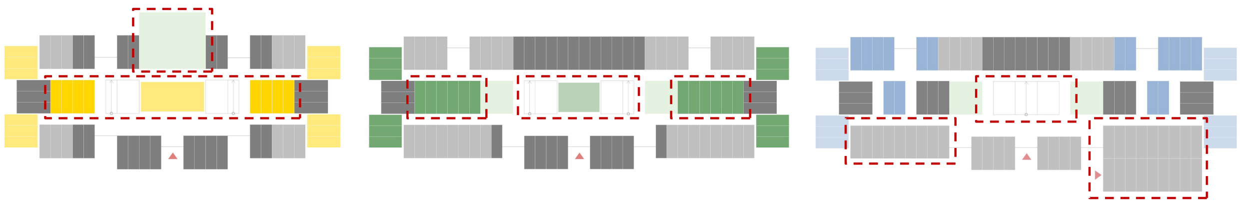


Figure 6. Building types: Kindergarten / Compulsory school / University (from left to right) [12].

module to the construction site without special transports. The module is a timber frame construction with bending-resistant corners. The modules can be brought to the respective location by crane and a specially planned lifting construction (Figure 5).

4.1. Material and system

The WOODUL consists of a room module with a load-bearing frame structure made of glulam. Through their combination, high levels of flexibility are eased, wherein open areas can be built when joint, or separated environment by inserting different planar elements in their interfaces. In this context, exterior walls element were also proposed as timber panelized system filled with wood fiber insulation materials. For the load bearing structure the group decided to choose glulam made from larch as it is domestic wood with a high density and stable. For the interior and exterior cladding, the student selected silver fir as it is also domestic, light and has very good properties in shrinkage.

4.2. Building types

The group used three different examples to show how their so-called "WOODUL" could function in a kindergarten, a compulsory school and a university (Figure 6). In the case of kindergartens, for example, the respective applications are geared towards sufficient movement areas and cloakrooms in the group room. In the case of the compulsory school, the group showed how central communal areas enable multifunctional uses, whereas the model for the university offers sufficient space for group work and lecture rooms of different sizes.

4.3. Case study compulsory school

The group convinced the jury of the flexibility of their system using various building typologies and showed the compulsory school type in detail (Figure 7). The building is entered centrally, after a few steps one is in the heart of the building, the entrance hall with the two staircases, which also function as a multifunctional community area. This point is the central hub of the building, connecting all accesses of surrounding classrooms. Generous atriums and glass doors at the ends of the corridors bring sufficient daylight into the interior spaces, while flexible interior walls create unique and changeable areas in shared spaces. In this case one classroom consists of at least 4 combined modules.

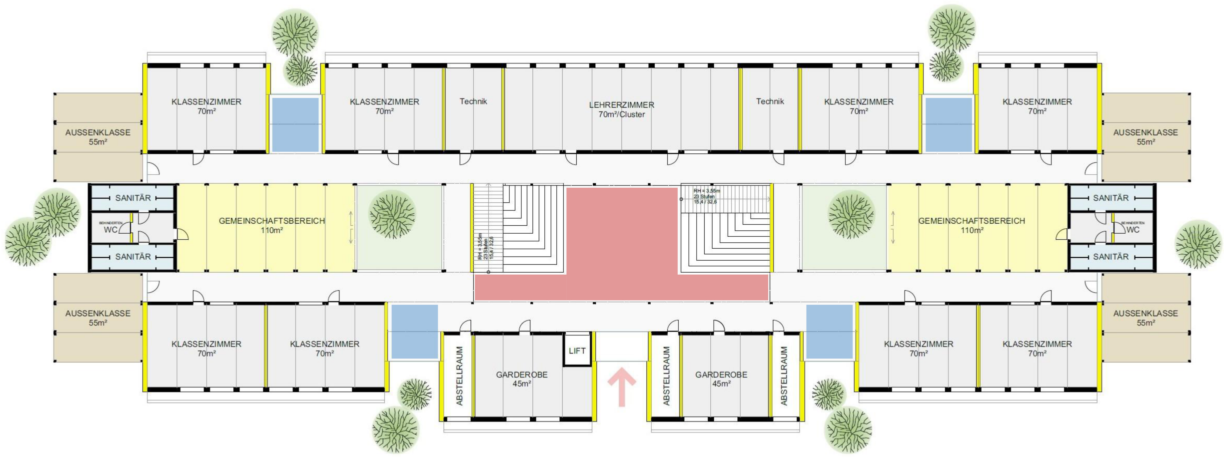


Figure 7. Floor Plan: Compulsory school [12].

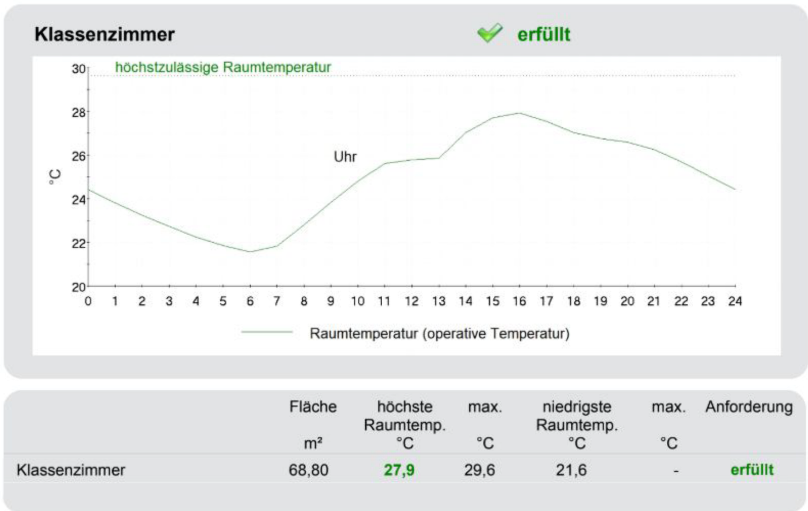


Figure 8. Calculation of summer [12].

4.4. Costs

The selected working group calculated the total costs, being 1 354 €/m^2 GFA (Gross floor area) for their WOODUL with by assembling costs of 116 €/m^2 GFA. They calculated as well the costs for a conventional container made of steel with a prize of 1 020 €/m^2 GFA. The higher costs were argued with the higher quality and better LCA in their project. One criticism that could be raised at this point is that no statement was made about the life cycle costs.

4.5. Energy concept

- Heating – underfloor heating operated by air-water heat pump.
- Hot water – decentralized tankless water heating directly at the tapping point.
- Ventilation – supply and exhaust air through ventilation openings with integrated fans. Supply air heating in winter.
- Cooling – ventilation concept.
- Power supply – photovoltaic system with monocrystalline modules on the flat roof.

4.6. Summer overheating

One of the tasks was the calculation of summer overheating according to OIB-Regulation 6:2019 and simulation according to ÖNORM B 8110-3:2012 (Figure 8).

Key data of the calculation:

- Classroom consist of 4 modules;
- 2× exterior walls;
- 2× interior walls;
- 1× floor to ground;
- 1× intermediate ceiling (warm);
- Useful area = 68.80 m^2;
- Number of persons = 30;
- Educational institution;
- Mechanical ventilation system;
- Shading by means of vertical lamellas;
- Night ventilation through windows.

4.7. Dismantling

A dismantling and reassembling concept of the WOODUL was developed as an integral part of the whole system. The concept ranges from dismantling individual structural elements to removing the underfloor heating system, describing in detail the assembly and disassembly process of the roof construction. They also calculated that the costs for dismantling will be at 98 €/m^2 GFA.

5. Conclusion

A paradigm shift in the construction sector seems inevitable to archive a sustainable development. The use of renewable and regional materials within circular constructions is seen by the experts as a key aspect to implement when aiming to reduce carbon emissions. In order to be able to fully exploit the potential of natural building materials and their implementation on larger constructions, the current training of civil engineers and architects in Europe is still inadequate [13]. Extensive knowledge and specific expertise on the subjects of architecture, material properties, structural engineering, fire protection, building physics and prefabrication is required. Herein, the design of timber buildings should be performed through an intensive collaborative and interdisciplinary perspective among all design team members including all disciplines, with the aim of developing an optimized holistic solution avoiding collisions, re-design and misunderstanding, what would bring cost and time overruns, dissatisfactions within the team or damages later on.

The results of the student projects were of high quality and also the learning factor was rated as very high. Students were confronted with the difficulties of working with various disciplines. They played their own role in an on-time, process-oriented organization of planning and learned the importance of each individual team member for the success of the project and therefore for the whole team. Furthermore, students also recognized the work of other disciplines as a valuable contribution to the entire process.

In the evaluation at the end of the course "Integral Planning 2", students gave the course a total rating of 91.8 %. The lowest ratings were received in the question: "Were the conditions for a positive completion of the course clear and understandable from the beginning?" (65.5 %) and "Was the content of the course structured?" (85 %). The highest approval with 99 % was given to the question: "Did the course promoted my interest in the content?" Furthermore, the students appreciated with high agreement the very open working atmosphere and the further development of their professional understanding.

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