Case Study

Systematic strategy to develop a concept for the extension of a hospital and to design an integrated private medical practice for radiology and radiotherapy.

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by

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Abstract

Like other branches, the health sector is also searching for new organizational forms in view of competitiveness. More and more, hospitals see themselves as integrated health care and service centers. This new view calls for structural and organizational consequences. This paper is to demonstrate how an architect can find systematically answers to these new requirements through his planning work. This paper presents a systematic strategy for the development of a concept for a hospital extension and also of the design of an integrated private practice for radiology and radiotherapy carrying out a fictitious conceptual study using the example of St. Elizabeth Hospital in Lörrach, Germany.

1 Background

Taking into account efficiency and thus competitiveness the health care sector sees always new efforts to develop management strategies to advance hospital operations. Outsourcing, i.e. subcontracting expensive services (such as radiology and radiotherapy) from an outside company is one alternative. Outsourcing makes sense if it is followed by a close and frequent co-operation. The combination of the capacity of the institution Hospital with the services of external providers, such as a private practice, contributes to the improvement of the care concept followed in the past: this co-operation aims at financing state-of-the-art technology and at the same time at profiting from synergy effects between the hospital and the attached privatized section in the full-time inpatient sector, the short-time inpatient sector and also pertaining to the care preceding and following inpatient treatment and finally in the outpatient sector.2

St. Elizabeth Hospital in Lörrach considers not only co-operation with a private practice for radiology and radiotherapy but also its integration on hospital grounds, which would involve a large amount of new construction volume and thus both organizational and structural consequences for the entire development of the complex.

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1 Note: This case study was done by Monika Fendl at the Chair for Social and Healthcare Buildings at the Dresden University of Technology, Germany, in order to prepare her research project about architectural design methodology which is financially supported by the DFG, Deutsche Forschungsgemeinschaft (the central public German Research Council), since May 2000.

2 Piksa, R Praxis, pp. 871-875; Barth, V Privatisierung, pp. 314-319 – both examples of projects put into practice: Auguste-Viktoria-Krankenhaus Berlin (Germany) and Städtische Kliniken Esslingen (Municipal Hospital) (Germany).
2 Aim

This paper aims at two essential issues:

1. Chapter 3 describes the strategy how a concept of urban and building design for a hospital extension can be systematically developed and realized in terms of planning. For this purpose, the complex task of planning is divided into subtasks and is solved in five steps.

2. Subsequently, chapter 4 gives a detailed description of the design resulting from the systematic development of an integrated private radiology and radiotherapy practice at the hospital site using the example of five essential stops on a patient’s way.

Thus this paper presents the practical application and also the results of a simple planning and design method to solve a complex planning problem. This case study deals in particular with the consequences resulting from the task given, i. e. to design an integrated health care and service center, while one must admit that the proposals made will probably go beyond the given financial scope. There had not been a final decision concerning the realization of this project until the design phase was completed. It is relevant to present this solution and the case study results, since this method for the solution of a complex planning problem – in accordance with the transfer aim of a case study – may be transferred to other practical cases.

3 Strategy

The strategy for the systematic development of a concept for the hospital extension is described in the following.

Step 1: General conditions for planning

On the one hand, the approach starts from theses concerning the well-being of patients and the medical staff and, on the other hand, from the physical requirements made on the structural shape of medical equipment:
Theses on the well-being of the patients and the medical staff

1. In terms of radiology and radiotherapy equipment the structural shape plays an important part, since it influences the well-being of patients and staff. A good design contributes directly to the therapeutic success by reducing patients' negative agitation and fears and giving them a sense of security at the same time. As a result, the patients are supported in their determination to recover.

2. However, there is also an indirect effect of the building’s architecture, since it increases the staff’s well-being and thus brings the medical staff to identify with their work places. As a result, the staff enjoy their work more and their well-being is transferred to the patients as well. We even have to start from the fact that the relationship between patients and the staff is of utmost significance for the well-being.

These theses do not only give the architect a good reason to justify the necessity of a good design, they also motivate investors to fulfil the functional spatial organization required. The following hypothesis is therefore formulated as the basis for the design work:

\[ \text{The structural shape has a direct and indirect effect on the well-being of the patients and can thus contribute to their therapy.} \]

Physics of medical equipment

Medical equipment causes radiation that can be classified in two basic groups:

1. Non-ionizing radiation, such as ultrasonic waves, electromagnetic fields and high-frequency radio waves are not harmful when they are applied within the generally accepted limits.

2. Ionizing radiation, however, puts matter into a charged state. This property altering the heritable information is harmful. Ionizing radiation comprises x-rays, in particular, radiation produced by nuclear matter (alpha.-rays, beta.-rays and gamma.-rays) and radiation generated by linear accelerators as well (e.g., electron, neutron, proton, photon and x-ray bremsstrahlung). Each type of radiation calls for specific structural shielding which – in turn – will effect to the design of the structural shape. It is, however, beyond the scope of this paper to go into the details of the various structural forms of radiation protection.

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Note: These theses have not exhaustively been investigated and scientifically confirmed so far. The authors, however, consider these theses to be a reasonable assumption for planning as a result of their own investigations.

Note: Although the truth of this sentence has not yet been proved, it will serve as a true assumption for further research work and thus for the deduction of theories and forecasts.

Fendl, M Milieu, (1999) and the references contained there – for further details concerning medical equipment and its structural shape.
Step 2: Development of a spatial and structural program

As the second step, a detailed spatial program has been developed on the basis of these many interconnected requirements, and the complexity of the functional radiotherapy units is covered by a structural program.6

For the radiology sector, the spatial program covers the reception, x-ray, x-ray computer tomography (CT), mammography, ultrasound, magnetic resonance imaging (MRI), angiography (using an x-ray radioscopy device), nuclear medicine (with gamma camera and positron emission tomograph (PET) as well as the social and the doctors' rooms and the facilities for supply and disposal.

The radiotherapy with reception, ultrasound, x-ray computer tomography (CT), irradiation planning, localization, radiotherapy (irradiation room), repair shop, mask preparation rooms, storerooms, the staff's and doctors' rooms and also the supply and disposal covers approximately half the area radiology takes up.

Step 3: Analysis of the building complex

As a next step an analysis has been made into the complex of buildings to find out about possible weak points (see Figure 1). As a result, such weak points could be identified that are related to shortcomings in site development (missing main access, interrupted progression) and also to the arrangement of non-medical functions (with a different floor-to-floor height) within the complex (nurses' home between ENT and surgical ward). From all these facts we can derive optimization potentials that are pre-conditions for the presentation and evaluation of development potential and finally for the choice of a preferred variant – in this case in the form of a site decision in view of an integrated medical practice.

6 Schossig, E; Damaschke, S; Scheffer, B Arztpraxen.
Since the present complex of buildings was built in several stages between the years 1913 and 1993, it is very heterogeneous. For this reason, a new building should have a simple and clear form that will be of a soothing effect for the present and the future situation. Beside the site decision and the design of the radiology and radiotherapy buildings, the aim is a design and development concept for the hospital as a whole – a concept that at the same time connects the functional areas separated from each other and optimizes the patient’s progression interrupted so far. This will ensure the micro-extendibility by single rooms and also the macro-extendibility by individual functional units along a main passageway.\footnote{Dirichlet, G L et al. Krankenhausbau – on the aspect of the central main passage.}
Step 4: Potential for development

The following criteria are taken as a basis for the assessment of the development potential of the complex: to maintain the open spaces and the villas in the west, to develop and build on hospital grounds only, to guarantee possible extensions along the main passageway and also links with the outpatients’ department/operating theatre and the residential care. Versions A and B (development toward the north) satisfy these criteria best. For this reason, we propose as the preferred solution the combined extension in the directions A and B together with the demolition of the unsuitable staff and clinic building in the northeast and the desolate nurses’ home in the southeast (see Figure 2). The integration into the given urban structure together with the structural and functional clarity of the new entrance building, which accommodates administrational rooms and also the integrated practice, will consequently form the structure-giving basis for the future development of the entire eastern hospital area. Moreover, this concept allows the hospital to be extended to the east in the future.

Figure 2: Proposed condition of the buildings
(site decision for the new entrance building and medical practice as structure-giving basis)
Step 5: Development study functional areas

Since the development concept and the extension potential should be accompanied by the practical arrangement of the hospital in functional areas and units\(^8\) to create a functional system and to improve the operational flows, the fifth step is to examine the arrangement of the functional areas on the basis of a site decision. As the analysis of St. Elizabeth Hospital inventory showed it was necessary to plan a rearrangement of the examination and therapy wards in view of the residential care and also the existing mezzanines (see Figure 3).

\[\text{Figure 3: Analysis of the existing functional areas (1st/2nd upper floor)}\]

\(^8\) Schmieg, H Zielplanung, pp 74-75.
For the above reasons the study shows ways how to *rearrange* the areas taking into account and securing essential correlations. At the same time, the operating block and the ICU are connected with the areas of examination, treatment and care. Functional 'islands' are eliminated and moved to places that are more useful (e.g., transfer of anesthesia; previously: between urology and neonatal unit, afterwards: between out-patient and aseptic operating block) (cf. Figures 3 and 4).

*Figure 4: Development study of the functional areas (1st floor)*

One of the goals of the German health service reform is interlocking out-patient and residential facilities while at the same time reducing the residential portion. To attain this goal the percentage of out-patient units (examination and treatment) has been increased compared to the residential units (care). This process may be measured using the new concept of the *out-patient indicator* $A_c$:

$$A_t = \frac{\text{area examination and treatment}_t \text{ in } m^2}{\text{area care}_t \text{ in } m^2}$$

$A_{\text{before}} = 0.60 \quad A_{\text{after}} = 0.96$
4 Results

The preliminary investigations clearly show: Even for the integration of only two additional functional areas (radiology and radiotherapy) it is inevitable to systematically work out complete concepts in order to lay the basis for a well-functioning overall concept in hospital construction. As a result, this case study deals with the entire spectrum – from the building complex in terms of urban design to the furnishings taking into account the theoretical aspects of planning. The main focus is on interior design. It is considered an essential part of the total building. Particular attention should be paid to the fact that the new central entrance building accommodating the administrative part and the integrated practice has the additional central task of image cultivation.

Radiotherapy is used as an example to explain to which extent the building design of this study fulfils the manifold requirements resulting. Here, the particular character of medical equipment becomes very obvious: the unusual aspects, such as radiation protection and statics are accompanied by psychological aspects, in particular, which considerably influence the patients’ well-being. Since this unit houses the entrance hall with the reception, the lounge and waiting rooms, the cubicles and the radiotherapy room as the five essential stops of the patient suffering from cancer, a short presentation of the design results for these stages will now be given:

**The entrance hall**

The central element is the entrance hall with reception and communication zones (see Figure 5). Its clear concept is to help the patient orientate thus reducing possible insecurity and removing barriers as the patient enters the hospital.
In the hall, there shall be stimulation of the senses in various screened sitting areas („Sit and Watch“), with water silently trickling down and feeding a watercourse, different surface structures stimulating the sense of touch, the fragrant blossoms of an evergreen tree and of course a cafeteria (see Figures 5 and 6).
Figure 6: Photograph of the model; view into the hall with reception and waiting room areas

The hall, which is orientated to the north, is not heated. The lounge areas (reception, seats and cafeteria) are heated by a combination of a local floor heating and a radiant ceiling heating that is included in the ceiling elements. The hall acts – concerning its building physics – as a conservatory. The sunlight coming in through the roof of the hall together with small diffuse heat gains cause the temperature to be 5 K higher than the outside temperature during the heating period. The hall is shaded with a textile shading device mounted on the roof of the hall to avoid superheating in the summer.9

Comparable data (climatological calculation of the school Bertold-Brecht-Gymnasium in Dresden, Germany) shows that the mean air temperature in the hall ranges from about 10 to 20 °C in winter and between approximately 15 and 30 °C in summer, while the outside air temperature is between −8 and 25 °C. The lowest air temperature in the atrium of the Bertold-Brecht-Gymnasium has been 5 °C and the maximum value has been 36 °C. All in all we can start from the fact that the hall with its heat protection glass will reduce the heat energy consumption. This is particularly true for the walls abutting on the patio. Proper evidence could be given by a dynamic calculation program.

9 Erhorn, H et al. Energieeinsparung pp. 159-162.
The hall roof construction is based on the ideas of Schlaich: It is made of pre-stressed diagonal ropes that are arranged in a mesh of equal squares, which produces a preformed section and consequently a spatial load-bearing structure.

The hall fulfils the fire protection requirements because of its horizontal division into fire and smoke sections, respectively. These sections are separated from each other by fire doors that automatically close in case of a given alarm and smoke or fire (heat) and which protect the glazed galleries (means of escape) from smoke. It is planned to equip the hall with a full sprinkling system – as it is normally used in hospitals – to compensate smoke and fight fire.

**The reception**

The reception as the central first contact gives the patient a first impression of the hospital. For this reason this area is designed in an open and friendly manner. It allows a smooth functioning and also sheltered confidential talks between patients and the medical staff. The hall is designed to avoid stress, to reduce barriers and anxiety, to provide good orientation and also to help patients find their way easily (see Figure 7).

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**Figure 7:** Floor plan, view, longitudinal and cross section of the reception area

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The generously designed reception desk accommodating several PC work stations and the switchboard is designed such that several patients/visitors may be received at a time. The task-oriented lighting directed towards the individual work stations and the general lighting of the reception area are combined in a way that they do not interfere with each other but generate a warm and familiar atmosphere.

**The lounge and waiting areas**

The waiting area is the place where the patient and maybe his relatives will sometimes spend a very long time. For this reason the patient’s social needs for quiet, information, communication and playing are to be satisfied here. Hence the waiting area should be divided into rather quiet and more lively spheres that are spatially and acoustically separated from each other and also into waiting zones for children. Therefore, the patients are being offered numerous different lounge and waiting zones that open onto the hall thus providing the patients with a more interesting waiting time as they watch what is going on in the hall.

**The changing cubicle**

The cubicle is a place of immense importance for the patients since here they are left alone with their thoughts and sorrows immediately before examinations or treatment commence. For this reason, meticulous attention is given to the fact that the changing cubicles are designed such that they fulfil the special needs of the patients. These needs particularly imply that the patients’ privacy is not violated (by the medical staff and other patients) and that they are acoustically connected with the environment. As a rule, we therefore recommend cubicles the walls of which reach to the ground but not to the ceiling.

There are two general types of lockable changing cubicles:

1. *Transit cubicles* with two doors, equipped with a seat, locker and mirror are very cramped as a rule. They offer the advantage that the patient may pass from the public waiting area immediately into the examination/therapy rooms.

2. A *one-way cubicle* with only one door may be designed more generously. However, this one door leads to an area for patients already changed and waiting to change, which might cause psychological stress on the one hand and disturbance for the patient’s privacy on the other.

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Miller, R L Hospital – cf. children’s waiting areas.
For the above reasons, we propose a transit cubicle that contains a seat and a locker, a generous mirror, which makes the cubicle appear larger and which may be used by the patient when sitting, and also a cloakroom area. The latter is defined by a darker color of the floor covering and is intended to make the patient divide his clothes into black and white (see Figure 8).

*Figure 8: Plan, view, wall design and derivation of the design structure of the changing cubicle*

**The irradiation room**

The well-being of patients who undergo radiotherapy is essentially influenced by the *design* and the *location* of the radiotherapy room and the way that leads there, but also – and first of all – by the medical staff’s behavior.
**Design of the radiotherapy room:** Figure 9 gives a summary of the aims and also the usual design means and Figure 10 presents a proposal concerning color and material design:

<table>
<thead>
<tr>
<th>Means of design</th>
<th>Aims of design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>to create a familiar atmosphere</td>
</tr>
<tr>
<td>Colors</td>
<td>to create a fresh and vital atmosphere (see Figure 9)</td>
</tr>
</tbody>
</table>
| Lighting        | chief aim: daylight illumination!  
                 | atmospheric lighting by various types of antidazzle lamps  
                 | make a distinction between: illumination for working, for treatment and dimming |
| Furniture       | to put away all necessary utensils and  
                 | to keep things in a certain order |
| Art             | an offer for optical change and for the patient’s relaxation |
| Plants          | patient’s relaxation |

*Figure 9: Means and aims of design for the radiotherapy room*
**Figure 10:** Presentation of color and material design by means of a collage

*Location of the radiotherapy room:* In radiotherapy the patient is subjected to high-energy radiation that is neutron and x-ray bremsstrahlung generated in a linear accelerator. This type of radiation is – as we have already mentioned – harmful when emitted without control. Therefore it has to be specially shielded. The structural radiation protection for radiotherapy rooms are walls and ceilings made of baryte concrete, which are about 1.5 m thick. This requirement naturally effects the statics of the building and thus the location of the radiotherapy room.
Standard solution: underground irradiation bunker

As a rule, these so-called irradiation bunkers are arranged underground, since this is the optimum solution in view of statics. On top of the bunker, further floors may be arranged so that the underground placement of the bunker results in a small surface requirement and thus in a dense structure (see Figure 11).

The lack of natural illumination is a critical issue: the medical staff accomplish their daily work without natural light, and the patient, who comes to the radiotherapy daily for about six to eight weeks, has to descend into the cellar atmosphere of the irradiation bunker.

**Figure 11: Standard solution: underground irradiation bunker**
Special case: Irradiation room on the ground floor with atrium

To eliminate these drawbacks the radiotherapy division may be arranged at ground level. A generously glazed atrium built in front of the radiotherapy room allows the radiotherapy room to be illuminated naturally. The static realization is simple and the expenses normally necessary for excavations for underground work may be saved. The distances may thus be covered without having to overcome level differences. The greenery in the atrium enhances the atmosphere in the radiotherapy room and gives the impression of a wider space (see Figure 12).\[^{12}\]

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**Figure 12: Special case: radiotherapy room on the ground floor with atrium**

For reasons of radiation protection this type of radiotherapy room may, however, not be built up, and adjoining structures may only be erected at the same level. Since this solution is impractical for a very high building density, the resulting high area demand is found disadvantageous. Strict measures of radiation protection would have to be followed, i.e. the atrium might not be entered from the outside.

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\[^{12}\] **Projektleitung Strahlentherapie** (ed.) Kantonsspital Aarau – cf. example Kantonsspital Aarau (Canton Hospital) (Switzerland). **Note:** Another example is Städtisches Klinikum Karlsruhe (Municipal Hospital) (Germany)
Innovation: Radiotherapy room on the top floor with rooflight

In dense inner-city areas the radiotherapy room may only be illuminated by placing the room in the attic in combination with a generous rooflight. This innovative solution does not exclude multi-story construction and it can do with a small built-up area. This design approach, however, calls for a sophisticated static solution (see Figure 13).

![Diagram](image)

**Figure 13: Innovation: Radiotherapy room on the top floor with rooflight**

This innovative approach has been specially developed for this case study, since it compensates the various disadvantages of the possible arrangements of the radiotherapy room mentioned earlier in this paper: A clear advantage of this solution is the unrestricted natural illumination available. The patient is lead upstairs, i.e. his way is ascending and is accompanied by the interesting impression of the hall that is passed (see Figure 14).
Figure 14: Ascent through the hall to the radiotherapy room (cross section)

The rooflight in the radiotherapy room does not only allow the sunlight to be used for natural illumination. It makes it possible to use the sun radiation for art installations that may help the patient relax. The shadowless glass construction of the rooflight lets the sun shine freely into the room. Crystal prisms disperse the sun rays into their overall spectrum. When the sun is shining the patient perceives this play of light in the room, where the resulting rainbow colors generate a positive mood. If the sky is overcast, the crystal piece of art offers the patient a means of visual activity while he is being prepared for the treatment (see Figure 15).

Figure 15: Cross section radiotherapy room
(Figure of the crystal prism taken from: MICROSOFT: Encarta ’95 Encyclopedia (1994))
**Structure**

A simple solution counteracts the theoretically higher static effort: Instead of carrying off the load of the two radiotherapy rooms over thick pillars – which would unfavorably affect the façade design – down to the foundation, we insert continuous load-bearing crosswalls the ends of which appear as narrow pillars in the façade. These load-bearing walls carry off the load of the walls and ceilings made of baryte concrete down to the strip foundations (see Figure 14 and Figure 16).

*Figure 16: Isometric view of the load-carrying structure*
**Efficiency considerations**

This innovative approach – both in terms of design and realization – forms the economic basis for the integration of a medical practice for radiology and radiotherapy into the hospital complex: The location of the irradiation rooms underlines the hospital’s orientation toward the needs of potential costumers. As a result, it will extend the hospital’s catchment area that is now estimated at approximately 150,000 inhabitants. The increasing influx of patients has to be transferred into monetary terms. The result is to be balanced against the increased structural and thus financial expenses. The increased structural expense is only due to the greater effort that has to be made for carrying off the load into the foundations. The increased expense is not caused by the irradiation room itself, because the expenses for the room remain the same irrespective of its location in the building. This is due to the fact that the requirements made on radiological protection must be fulfilled on five sides of the room, anyway. If we consider this differential investment from the point of investment theory, a net present value $\geq 0$ is to be demanded in order to convince the individual decision makers.

5 **Summary**

This Case Study: Systematic strategy to develop a concept for the extension of a hospital and to design an integrated private medical practice for radiology and radiotherapy is to illustrate the practical application of a systematically structured strategy that can be used to handle complex design problems as we find them particularly in hospital and healthcare facility construction. Special attention has been paid to such issues as management, well-being of patients and staff, physics of medical equipment, functional and organizational correlations and also the design objective. Therefore, the design work has been divided into sub-processes that were completed in steps. This exemplary strategic solution is presented to handle complex tasks. The resulting findings refer to the individual actual project to be planned. This strategy may – in accordance with the general intention of a case study – be transferred to other projects including the user groups concerned (stakeholders).
6 Epilogue

The potential solutions for the structural extension and development of a hospital, which have been systematically developed within this case study, together with the suggested building design for a private practice focus on the discussion about the topic high-tech medicine versus human scale and they aim at spaces being part of the therapy. In this respect it is extraordinarily important to focus one’s interest on the user groups patients and medical staff, since the patients find themselves in an extremely weak mental and physical situation and the staff are daily doing their work in the hospital strongly influencing the patients' well-being by establishing social contacts. Structural shape objectives in the form of planning approaches may be derived and put into practice using the particular experience and the needs of the user groups patients and medical staff – not only taking into account the architect’s own experience. A structural shape, which is functional, attractive, solid and thus lasting, may only be achieved by involving patients and the staff into the planning process. As a consequence of growing competition, customer orientation and, as a result, the patient’s, i.e. the customer’s well-being will become an ever more urgent target issue in the future. This, in turn, will stimulate hospital and private practice managers to invest their money not only in good staff and state-of-the-art medical equipment but also in the structural shape, as a natural consequence. – And this is just the point for the architect to step in.

Acknowledgement

We would like to thank Ms Katrin Pönisch-Pörschke from the Language Center of the Dresden University of Technology, who committed herself greatly to the English translation of this article.
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