ADAPTABILITY OF HOSPITALS – CAPABILITY OF HANDLING PHYSICAL CHANGES

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ABSTRACT

Since hospitals deal with changes more than any other category of buildings, the cost involved due to this can be reduced, provided the construction is prepared for such type of changes (i.e. Adaptability = capacity for handling changes). This paper presents a brief characterizing of the physical changes done in 6 Norwegian hospitals the later decades, together with a survey and a mapping of what kind of actions have been taken place in order to give high physical capability and flexibility of the building structure. This was done by using a mapping method for adaptability, inspection of the buildings and semi-structured interviews of both users and the facilities managers. The objective is to get an overview of which principles and solutions that seem to be profitable by looking at the numbers of change and the causes for it.

KEYWORDS hospitals, user demands, adaptability, changes

INTRODUCTION

Norwegian hospitals will face great challenges in the years to come that will influence the hospital management and facility management services. One of the challenges will be to deal with various conditions and age of real estate. Significant periods of hospital developments in Norway have been in the 50's and the 70's with functionalism as the main building style. This way of designing buildings reflects the focus on efficiency and uniformity of how to operate the hospital. The design and the functionality were based on the hospital organization as professional units underlining efficiency and productivity. Today's trend goes towards a greater focus on the patient as a customer of health care. This leads to a patient focused design concept that supports the patients and their needs rather than focusing on a way of organizing according to medical units (staff and discipline focused). This trend is also responsible for changes in existing hospitals.

Pilosof et al (2005) mentioned that the future remains unknown; planning for change is still, more than ever, one of the great challenges facing the hospital designer. He also mentioned that the more complex physical environment the more problematic it will become to modify. He points out the *paradigm shift* taken place since the 70's until today: that the technological approach has been exchanged for a holistic one; like the labyrinthine corridors and the abandoned esplanade and courtyards have metamorphosed into an open, light, green atrium. One question he raises; can a hospital truly combine the technological with the human?

A study of some hospital projects (Bergsland et al, 2000, Valen et al, 2005), shows that one of the major challenges for the hospitals is to adjust existing buildings to new demands and needs that mainly ends in reconstruction and sometimes extensive alteration in addition to new buildings. In order to handle changes in functionality, assignments and activities, the hospital buildings and infrastructure must be continuously updated with the hospitals tasks that are capable to adjust to the given limits of physical and technical design. Therefore, the healthcare campus, with a conglomerate of various buildings from different time periods and varying architecture will continuously be going through renewal through strategic removal of individual buildings. Issues of expansion, adjacency and sustainability of the hospital as a whole might be best served by a campus approach.

A central question is how or whether existing hospitals can meet all these demands for changes? Do the buildings have necessary physical adaptability? What principles and physical solutions are profitable in order to increase the buildings ability to handle change? The question is which actions will give a positive effect on economy, efficiency and quality of the health production over time. By studying a selection of hospitals, looking at what kind of changes they have handled since completion and the causes for these changes, some solutions can hopefully be pointed out that can give a better and more efficient hospital as well as a longer functional life time. This paper focus on how six hospitals in Norway, four university hospitals and two local hospitals, have handled changes (since completion) due to new demands, organizational changes or new medical technology. Another question is how these hospital buildings were prepared for and handled the changes, technically and physically. The main purpose of this paper is to demonstrate the principles and solutions that are presumably profitable, when planning the hospital of tomorrow, knowing for sure that changes will come.

ADAPTABILITY OF HOSPITALS – NEED FOR THE PRACTICAL SOLUTIONS

Bergsland et al (2000) found that most hospitals focus on these conditions in order to handle changes in the future. They investigated how several newer hospitals in the latest decade had practised the concept flexibility both in the planning and the construction phase. Bergsland et al categorizes adaptability of hospitals into the following properties when it comes to the physical structure of the hospital:

- Design concept
- Dimensions – construction (core space, floor plate dimension, interstitial floor), standardization of rooms, area reserve and capacity of HVAC, wiring and ICT.
- Layers, structure and zonation
- Standardization – modularity, generic rooms, less variation of room size
- Vertical and horizontal expansion – construction

In general, flexibility of hospital buildings, as described by Tannis Chefurka et al (2005) and Pilosof (2005), is a matter of:

- A master plan for campus, whole view of the ongoing operation of the entire organization
- Possibility for horizontal expansion into other functions
- Possibility for vertical and horizontal expansion (Load capacity, Floor plate size, Challenge of link between multiple floor levels, Departmental adjacencies – floor plate size too large gives limiting access to daylight)
- Enough corridors and core space
- Municipal site services
- Capacity for Air handling system
- Modularizing and grid

- ICT capabilities
- Standardization of rooms

This paper focuses on the overall adaptability of the physical hospital building by looking at properties that describe the physical and technical infrastructure, area reserve, expansion possibilities and extra capacity of construction (load capacity, floor height) and technical supply (HVAC, wiring, ICT). Here we use the concept adaptability of the building as a combination of the terms flexibility, generality and elasticity.

We are examining the physical changes in six Norwegian hospitals with buildings from different time periods. The intention has been to map all main physical changes done during the buildings lifetime. The changes examined are classified into four types: relocation of function, refurbishment and renovation (R), vertical or horizontal expansion (V-ex or H-ex) or addition (A) of space due to one of four causes categorized as: new demands (D), organizational changes (i.e. reorganizing of functions or units) (O), new medical technology (MT) or others (O) such as adding more service functions or HMS actions. New demands can typically be new laws and regulations, demands from users to keep up to date standard and comfort etc. Organizational changes (O); i.e. relocation of bed wards and operation units can be rearranged in order to reduce time and distance, improve logistics and/or increase productivity. I.e. the latest decades orientation towards the "patient in focus"-philosophy has led to organisational changes in hospitals. New Medical technology (MT) can either increase or decrease the need for space, like new MR equipment or electronic patient journals. It also may lead to the need of special reinforcements of floor plate or special suspension in floor plate.

These questions are investigated by studying project reports, articles and hospital documents like a space plan, interviewing technical and management personnel of the hospital, as well as consultants and architects involved in the planning process of the hospital. The main physical parameters that characterize the adaptability are charted by using a matrix method developed by Multiconsult in 1998. This method covers most of the parameters as mentioned above. The method is further described in Larssen and Bjørberg (2004).

When planning new hospitals today physical adaptability of the buildings and a concept that support organisational flexibility is often in focus. However, the solutions chosen differ from project to project. Often also investment in adaptability/flexibility is cut when it comes to the hard priorities of scarce financial resources. Also some of the solutions i.e. standardized room sizes leads to increased area and also increased operation cost as well as construction cost. However, experience of several hospital projects show that the total construction cost corresponds to two or three years total operation cost (ref. Rikshospitalet). Failing to invest in adaptability can have dramatic negative consequences on the operation costs over time.

CASE STUDIES OF SIX SOMATIC HOSPITALS

Since January 2002 the public hospitals in Norway have been organized into five regional health authorities (RHA). Key figures of the six somatic hospitals located in the different Regional Health Authorities (RHA) are presented in Table 1. Figure 1 shows the location of the case hospitals within their respective RHA.

Table 1. Key figures (2004) - bed capacity, operation cost, man labour year, no. of in-patients and out-patients, no. of inhabit. in their respectively health regions. (Source: Annual reports, 2004)

2004-fig.	No. of inhabitants	Bed capacity	Oper. Cost mill NOK (mill EU)	Man Labour Year	No. of in-patients	No. of out-patients	Total space (BRA m2)
Total, somatic hospitals	4 606 363	13 029	46,670 (5834)	63 498	841 790	3 374 388	-
St. Olav	645 700	1065	4,66 (583)	6755	333 580	285 979	-
Rikshospitalet	895 388	585	4,35 (544)	4167	78 000	173 000	228 263
Haukeland	948 479	~900	5,182 (648)	6751	356 335	352 514	125 000
UNN	462 640	450	~ 3,1 (387)	~4500	-	-	~78 000
Elverum	1 654 156	-	-	-	48 446	67 458	-
Levanger	645 700	-	1,455 (182)	1973	130 772	96 282	63 000

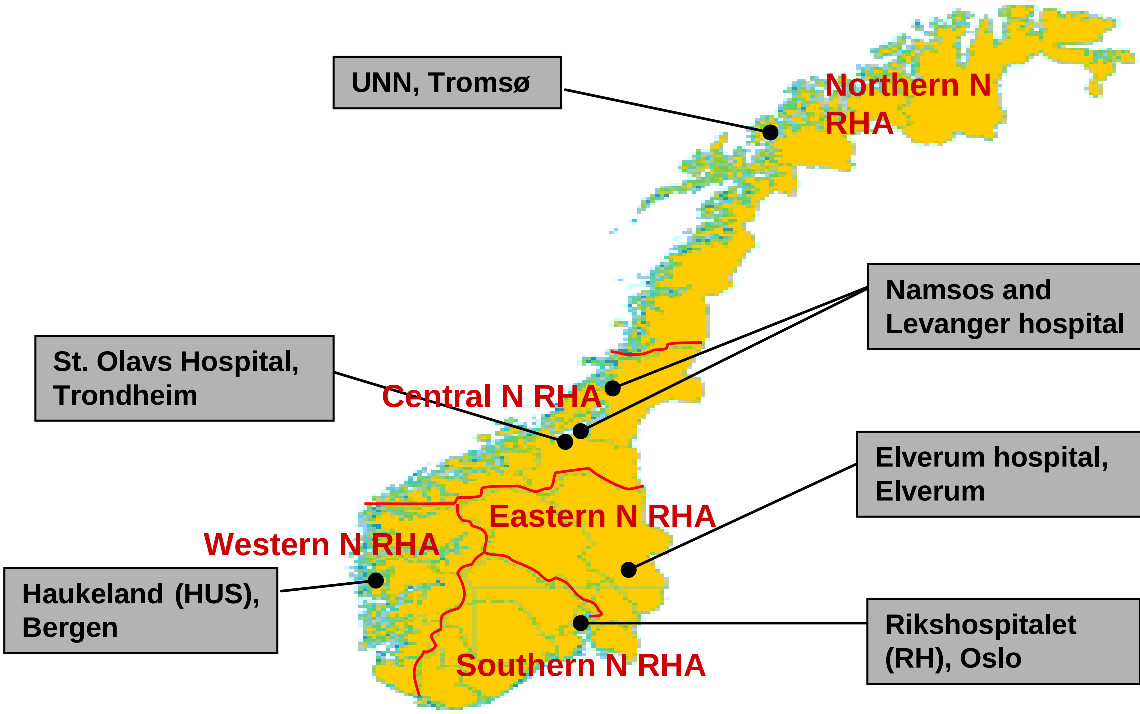

Figure 1. The five Norwegian Regional Health Authorities (RHA), the location of the six cases; four university hospitals (Bergen, Oslo, Trondheim, and Tromsø) and two local hospitals (Elverum, Levanger)

St Olavs Hospital - University Hospital in Trondheim (– to be finished in 2014)

The patient focused design concept has been used in the planning of the new St. Olavs Hospital. It is organized by a centre model, with link between the centers by communication bridges. Adaptability is highly focused in the planning process, with the intention of a robust concept to handle both organizational and physical adaptability over time (www.helsebygg.no).

Rikshospitalet (RH) – A new university hospital in Oslo

The new university hospital, opened May 2000, is the hospital with the best and highest technology in Norway serving all the people of Norway. However, patients mainly come from the South N RHA and East N RHA, 28 % and 59 % respectively (Rikshospitalet, Annual report, 2004).

The architectural design has focused on air and light, based on the idea of a humanistic hospital, where shape, colours and materials takes care of the people and creates a sense of safety and comfort (www.rikshospitalet.no). The building is low with direct visual contact with the nature outside. The hospital is built with the intention of physical adaptability and possibilities for continuous change in tasks and organisation. The “heaviest” functions regarding treatment and technical demands are located along the middle of the building structures.

Haukeland University hospital in Bergen (HUS)

The central building (completed in 1983) is chosen as case. It is the compact and large building in Figure 3 (or no. 30). It is characterized by a massive, large building structure in the lowest floors, with two “crosses” in the upper floors. The functions regarding treatment and technical demands are mainly located in the lower floors.

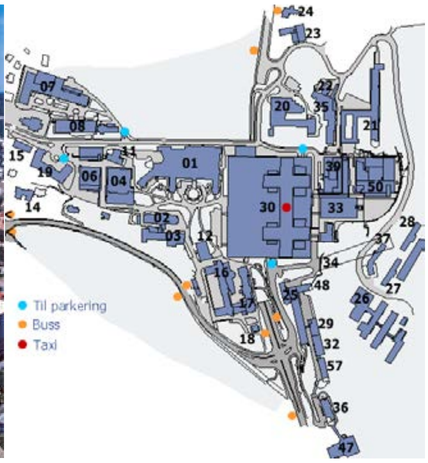

Figure 3 and 4. Haukeland University hospitals (HUS) in Bergen, one of the largest and most specialized hospitals of the Nordic countries (Source: http://www.helse-bergen.no)

University hospital of Northern Norway (UNN), Tromsø

UNN was opened in 1985, and according to the hospital director the first refurbishments started already the day after the opening ceremony. The hospital was planned as a rather traditional hospital without having much focus on adaptability issues. The building complex is adapted to the falling terrain, and consists of a central building structure with several wings on each side. The hospital site is large and has good possibilities for both extensions and additions of buildings.

Sykehuset Innlandet HF – Elverum hospital, Elverum

Elverum hospital is a local hospital with buildings from different time periods, the oldest from 1925, the others from 60's, 70's and 80's. This hospital is, in that way, characteristic for many existing hospitals, with a conglomerate of buildings, built at different time periods, with various architecture and physical properties, without any specific concept or philosophy behind that ensures the totality of the structure.

Levanger hospital

Levanger hospital is a local hospital with buildings built from 1916 till 2005 and in many ways similar to Elverum. Levanger also consists of a conglomerate of buildings, built at different periods with different architecture and physical properties, without any specific concept or philosophy behind the total structure. The somatic part of the hospital is part of the case study (buildings A, C, D, M, B, I and G).

RESULTS FROM THE SIX HOSPITALS

Overall results for the six hospitals are presented and commented in this section. A summary of some results from the mapping of technical and physical properties relevant for physical adaptability per hospital building is presented in Table 2.

St. Olavs Hospital has focused on physical adaptability to meet future changes, i.e. by using interstitial floors above the operation suites and image diagnostic area. Floor heights and load capacity are relatively high. The interior walls have no bearing loads or built-in technical installations, which makes changes and refurbishments easier. The surplus capacity on HVAC is 20-30%. The technical grid is 7.2x7.2m, which gives possibility for large open spaces, without columns. The hospital is planned with a high amount of standardized room sizes that prepares possible use for several functions. Also the wards are built with standardized modules that easily can change 2 bedrooms into i.e. offices. St. Olavs Hospital has also focused, especially, on clusters of bed wards with generic size and a short distance to functions and supplies (patient-focused). All centres have possibilities to expand into the neighbourhood (supports organisational flexibility). All the operational suites are connected between the centres with bridges at the second floor. A horizontal extension of the buildings is possible giving a total area reserve of 62,000 m^2 of day light area.

The *Rikshospitalet* project focused on adaptability, i.e. by using interstitial floors above high-tech functions, such as operation suites. The modularity gives room for relatively large open spaces. Floor heights are relatively high (3.5-4.0 m), and load capacity is high. Interior walls are not bearing load and have not built-in technical installations. The original rest capacity for technical installations (i.e. HVAC) is already used, and rest capacity is now limited. The hospital was planned with possibilities for horizontal expansions, and 5-6 years after the opening of the hospital the capacity of the site is fully used. It is still possible to add a floor on several parts of the building, but this will represent a break with the concept of the low building structure.

Table 2. Structural and technical flexibility for technical and physical properties of the selected building, year of construction and area (m2 BTA). (Source; informants and reports, Valen et al., 2005, Gulbrandsen and Andersen, 2005)

PERFORMANCE CRITERIA						
Hospitals	**St. Olav**	**RH**	**HUS**	**UNN**	**Elverum**	**Levanger**
Construction Year	2014	2000	1983	1985	1925/1965/ 1984	1972/1995
Area (m2 BTA)	222 971	228 263	~125 000	~78 000	10 988 3 345 16 690	12067
STRUCTURAL AND TECHNICAL FLEXIBILITY						
Interstitial floor	yes	yes	partly	partly	no	no
Floor-to-floor height	> 4 m	3,5 – 4 m	3,5 – 4 m	3,5 – 4 m	3,0 – 3,5 m 3,5 – 4 m 3,5 – 4 m	3,0 – 4 m
Floor loading capacity	4-5 kN/m2	> 5 kN/m2	4-5 kN/m2	4-5 kN/m2	<3 kN/m2	3 kN/m2
Possible open space (modularity)	Very open	Open	Less open	Less open	Less open	Less open
Corridor space	-	2,4 - 3,0 m	2,4 - 3,0 m	>3 m	2,4 - 3,0 m	-
Core space	Spacious/ Very Good	In exterior wall	Less Good	-	Spacious	-
Internal wall	Light no load	Light no load	Light* no load, some install.	Light no load, some install	Heavy, carries load	Heavy, carries load
OTHER FACTORS						
HVAC - surplus capacity	20-30 %	limited	0 % left	30 %	-	-
Horizontal addition - Site exploitation	Good 50 %	Limited	Limited	Good	Some	Some
Vertical addition - one or two floors	No addition (?)	one floor	one floor	two floors	No addition	No addition

* Some installations are located in internal walls in corridor
- Unknown

Haukeland has interstitial floors some places. Floor heights are medium and load capacities good. Possibilities for larger open spaces are limited, due to columns (limitations in modularity). Interior walls are not load bearing, but have to some extent built-in or crossing technical installations. There is no surplus capacity left on HVAC. It is possible with vertical extension of one floor, but limited possibilities for horizontal expansions.

*UNN***.** Floor heights are medium and load capacities good. Possibilities for larger open spaces are limited, due to columns (limitations in modularity). Interior walls are not load bearing, but have to some extent built-in or crossing technical installations. Surplus capacity of technical supplies (i.e. HVAC) is 30%. Less standardized size of rooms. The hospital was built with possibilities for both vertical and horizontal extensions, as well as possibilities on the site for new buildings. Adaptability and the need for future changes were not given much attention during planning.

Elverum. There are no interstitial floors. Floor heights is low in parts of the buildings, and relatively good other places. Load capacity is limited. High amount of heavy, load bearing interior walls that limits flexibility. Possibilities for larger open spaces are limited. No possibilities for vertical extensions, but still some possibilities for horizontal expansion.

Levanger. There are no interstitial floors. Low floor heights in parts of the buildings, and load capacity are also limited. High amount of heavy, load bearing interior walls that limits flexibility. Possibilities for larger open spaces are limited. No possibilities for vertical extensions, but still some possibilities for horizontal expansion.

Figure 4 shows the reported frequency of changes per decade for each of the hospitals while Figure 5 shows the number of types of changes. The frequency has increased the last 3-4 decades. It is interesting to register that the new Rikshospitalet, which was opened in 2000, already has been through 30 changes during the first 5 years it has been operating. With no surprise, most of the changes are refurbishments, relocation and changes in existing buildings, but there are also quite a lot of extensions and addition of new space. Figure 6 presents the type of change vs. the causes of changes per hospital. Obviously the main changes are categorized as relocation of new functions and refurbishments due to organizational changes (O) and reasons and new demands (D).

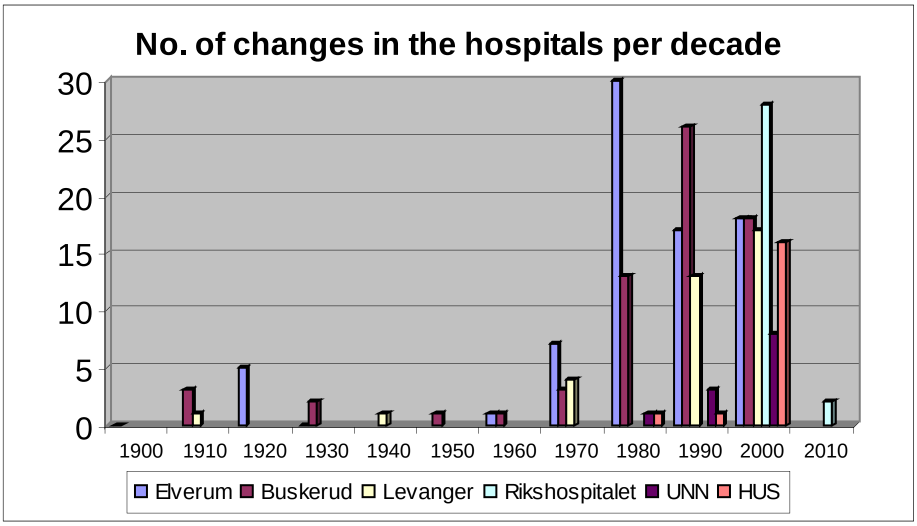

Figure 4. Frequency of changes over time per decade per hospital.

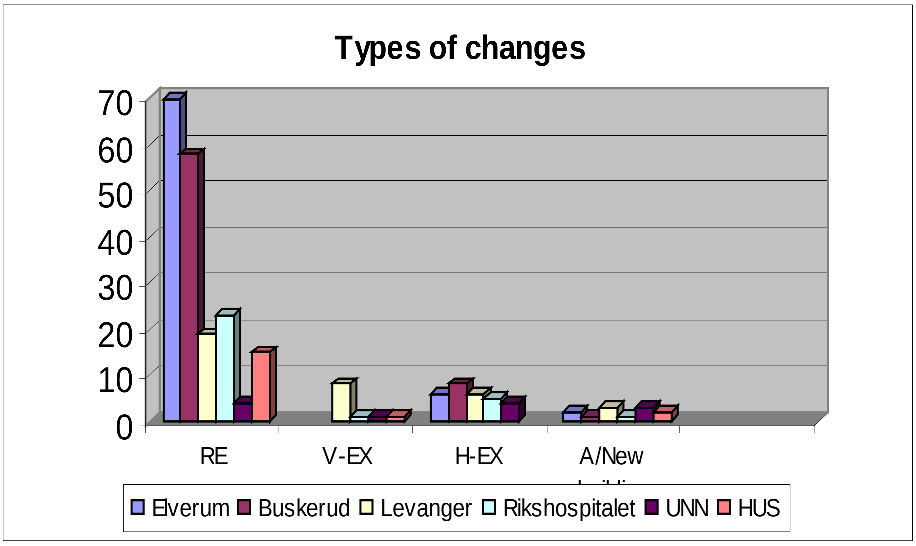

Figure 5. Number of changes per type of change per hospital, characterized as relocation and renovation of space (R), vertical and horizontal extension (V-ex and H-ex) and new buildings/addition (A).

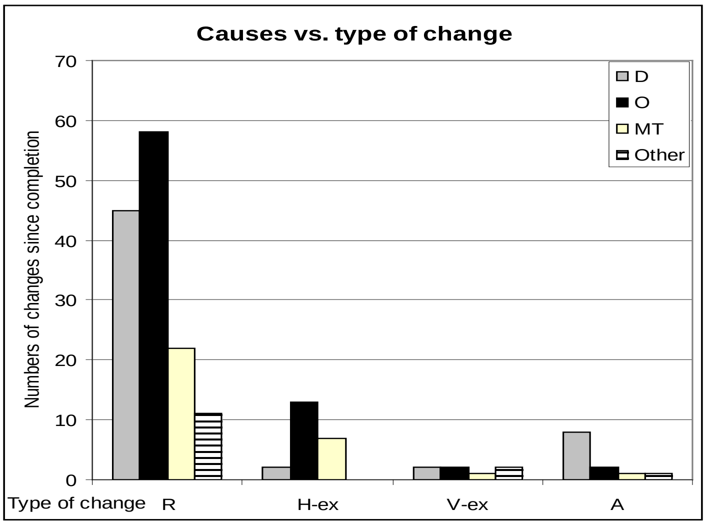

Figure 6. Total number of changes due to new demands (D), organizational changes (O), new medical technology (MT) or other reasons vs. types of changes (relocation, renovation or refurbishment (R), horizontal or vertical expansion (H-ex / V-ex) or addition (A)

HOW WELL THE CASE HOSPITALS HANDLED CHANGES?

The issue has been raised in this study of how these case buildings were prepared for changes, technically and physically, and how their ability to handle changes were due to new demands, new medical technology, organizational or development reasons. The purpose was to demonstrate what principles and solutions that have been obviously useful and profitable in the long run. Common for all the cases since completion is that the buildings have been through a huge amount of changes, mainly numerous relocations and refurbishments, but also several periods with additions and extensions. The main causes for change have been new demands, organizational changes, new medical technology and treatment methods.

The study also shows that the frequency of change has increased rapidly for the last 30 years and for each decade. However, there is an uncertainty in the source of information since this depends on the knowledge of the facility management staff and whether they have information about older changes. Probably further changes could have been registered. Changes are also painful and disturbing for the staff; it takes time and disturbs the production and the health service offered to the patient. In many cases production stops and reduced productivity during construction work costs even more than the refurbishment cost itself.

The most useful and profitable actions pointed out in these cases are connected to:

- Design concept and master plan - allowing changes of function or growth at adjacent area; possibility for vertical and horizontal extension.
- Generality - modularity that gives room for larger open spaces, sufficient load capacity to serve different functions and installations/equipment, sufficient floor height to serve several types of functions and equipment/installations, more use of standardized room size and less variations in room size.
- Flexibility – design that supports the possibility to make frequent changes in the interior plan, technical infrastructure and new equipment, such as i.e. flexible interior wall systems, sufficient floor heights and/or interstitial floors.

- Surplus capacity of core space, technical installations (HVAC, wiring, ICT)

A good design concept which ensures good functionality, efficiency and a working environment where staff feel comfortable will also give good curing environment for the patients. However, it is also important that the building is designed for handling physical changes. A question is how the design concept handles how the building matches the hospital organisation over time. In this study the concept of the University hospitals and Rikshospitalet so far has been a success considering handling changes due to area reserve and adjacency possibilities. They confirm that preparing for expansions, especially horizontally but also vertically were profitable. All cases that were prepared for extensions (horizontal and vertical) have more or less been utilized. Others have not followed the design concept or a master plan, or they simply lack a holistic plan for the campus. These hospitals have increased in space, resulting in a campus with a conglomerate of buildings with various architecture and functionality, not to mention the challenge for the holistic logistics of the hospital. One of the cases reports problems to efficiently locate related functions within the same area because of limitations in the shape and structure of the building.

Hospital buildings completed during the 21st century have a better adaptability than hospitals built in the late 50’s or 70’s. This due to the fact that the building tradition of the latest years, that used more load bearing external walls and larger spans instead of internal load bearing heavy walls, give possibilities for more open space and using larger floor height than during the 50’s and the 70’s. Changing plan due to refurbishment and relocation is characterized as most frequent in the case hospitals. Physical properties improving the *generality* and *flexibility* is therefore essential, and properties found useful are several. Having enough floor height makes it possible to easily change and access technical installations and gives fewer problems with suspension of medical equipment. It is also a limitation to alternate use of space, when the floor height is low. Interstitial floors can in many cases compensate for low floor heights. Interstitial floors have been useful where built over zones with heavy technological equipment and complex technical infrastructure, e.g. operation units or diagnostic centres. It makes change easier with less cost and less disturbance of the health services. Rikshospitalet confirms this saying that many of the changes have not been possible without the interstitial floor (fl. Ht= 1.9 m). When it comes to standardized room sizes St. Olavs Hospital is first using more standardized sizes for i.e. bed (~14-16 m^2) and examination rooms (~16 m^2).

Surplus capacity on HVAC, wiring and ICT has been utilized maximally and is clearly documented as necessary. The New St. Olavs Hospital prepares for a surplus capacity of 20-30%. How large the surplus capacity should be depends on what you think of the future. It is also a question of cost. In theory we are assuming that buildings with physical properties that give room for future changes (a high degree of adaptability) leads to more and less costly changes than a building where changes are hard and costly to perform (low degree of adaptability). However, several actions to improve adaptability gives increased construction cost and the benefit will always be considered. Does this lead to lower operational and development cost in the total life time? And what is the expected positive effect on the economy and quality of the core business?

One of the largest challenges that the Norwegian hospitals will face considering existing buildings, is to decide what is still functioning and what should be demolished and rebuilt, eventually relocated. An important question here is to what extent existing buildings can be adapted to demands of today and of tomorrow. These decisions will in the end be a matter of adaptability and value of usability for possible other use.

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