NEW DESIGN APPROACH FOR FIRE SAFE HOSPITAL WARDS

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ABSTRACT

The fire safety strategy of hospitals does not take into account the actual evacuation times of different types of hospital patients. Designs of hospital wards with bedridden patients are focussed on maximum fire compartmentation. This paper describes a more integrated approach for designing or adjusting hospital wards, where different parameters can be chosen and compared.
The present study focuses on the evacuation process, and was conducted into the actual evacuating time of a hospital patient, including the disconnecting time of different types of hospital patients. With the derived data evacuation times of different hospital wards can be calculated.

INTRODUCTION

Designs for hospital wards do not explicitly relate the required safe egress time of a ward to the actual fire risks that are present at this ward. As part of a study underpinning new hospital fire design strategies, experiments have been carried out in two hospitals to determine the time required to evacuate different types of patients in different types of wards. In an integrated approach to design, the required time for safe evacuation of a hospital ward needs to be calculated, differentiating between types of wards, and should be matched with the fire safety risks present at the different wards. This will give more insight in the actual fire safety of hospitals wards.

The main concern of fire safety in hospitals is that there is no complete insight in the real egress time of patients, especially of vulnerable and bedridden patients. Data of egress times is not categorised, and the data is not complete. The Dutch regulations (based on research done up to 1994 and on common knowledge and assumptions) are still based on old principles of healthcare. These regulations are based on larger patient rooms (6 patients per room for a standard ward) forming a 30 minutes fire resistant (sub)fire compartment and corridors that are only used as circulation space [1]. In this 'old' concept corridors are considered safe for egress. In the regulations corridors should only be used as traffic space, and are considered as safe for evacuation purposes. One should be able to evacuate patients to a safe zone (other fire compartment) on the same floor.

Design trends for hospitals are new concepts like "healing environment" with mostly smaller individual patient rooms and more spacious corridors with more functions. The corridors serve more as a living room for patients, a place to store equipment and to charge electrical devices. With this tendency, higher fire risks are introduced within these corridors, possibly leading to less available safe egress time. Economic pressures drive the staff-patient ratio down, especially during weekends and nights, whereas more patients who require more intensive care (within this context, they may be connected to a lot of equipment) are being nursed in normal wards instead of in intensive care units.

The presence of vulnerable and dependent patients who need expert assistance during evacuation requires extra attention within the fire safety concept for a hospital ward. But research in evacuating different types of patient rooms showed the time required to evacuate bedridden patients can be significantly higher than previously thought [2]. These developments all ask for a more detailed approach, considering realistic egress times for the patients concerned and a staff-patient ratio that fits within the fire safety concept of a ward. The traditional regulations seem to be simplified and not fitting to the needs of the current design trends.

Current fire safety concept

In the figures below the fire safety concept based on the regulations is explained. A hospital ward is a fire compartment with multiple patient rooms, each patient room is a sub fire compartment with a self-closing door. Rooms for 6 patients were common until recently. When a fire occurs in a patient room a fire alarm will be raised, either by a patient or by a smoke detector. Two members of staff arrive at the threatened room within two minutes after the fire alarm and evacuate the room within two minutes after arrival. When the room of fire origin is evacuated, the other rooms on the hospital ward are evacuated if necessary. There is sufficient time for evacuating the other patient rooms, because the corridor remains smoke free for a prolonged time. A fire does not start in the corridor itself or in a common facility room in the ward. The fire is contained within the ward by the fire compartmentation, and assisted by the emergency services who intervene after 20 minutes.

Patients are evacuated to a safe zone (other fire compartment) on the same level. Further evacuation of all patients in the hospital is not foreseen. If a fire escalates, a total evacuation must be undertaken without special facilities. This concept, laid down in the Dutch regulations for hospitals, is not an exception internationally. In various countries in Europe regulations for hospitals are based on the same principles [3].

Figure 1 & 2. Traditional concept of evacuating a hospital ward

The research is focused on the first part of the evacuation, evacuating patient rooms and an entire ward, ending in an adjacent fire compartment. Significant differences in evacuating times can be expected between different types of patients. The regulations do not take into account the longer time needed to evacuate bed ridden patients, who are fully dependent on assistance by staff. In the regulations the maximum allowed evacuation time per (sub)fire compartment is 1 minute, and it suffices to provide a minimum door width for compliance. Expected significant delays due to disconnecting and evacuating multiple patients are not recognised by the regulations. There is also no specific calculation method required to determine the evacuating time of persons who need assistance during evacuation. It is implicitly considered that there is enough staff available to guarantee a safe evacuation of the patients concerned. Therefore hospitals form some sort of grey spot because they do fulfil the limited requirements in the regulations, but do not focus on the actual situation present.

Research conducted

There is a lack of knowledge on the actual disconnecting and evacuation times for specific patients. A series of evacuation experiments has been carried out in different types of wards in two hospitals. The actual time needed to disconnect patients from all equipment and the time needed to prepare them for evacuation has been determined as a component of the total egress time per patient. The different parts of the total evacuation, such as the time needed for the staff to reach the patient, leaving a hospital room with the patient and passing a self-closing fire door have been recorded and analysed.

The time it takes to disconnect patients from equipment so they can be evacuated from their rooms have been gathered for Dialysis, Standard, Intensive Care, Neonatal, ICU, Heart monitoring and Recovery patients. Different staff members did take part in the experiments. The analyses show the differences in the total egress time between staff with working experience in that specific ward and staff that is not used to work with these patients. With the data collected a tool was created to design 'sufficiently safe' hospital wards. It is important for a hospital designer to have a tool that makes it possible to strike a balance between the level of safety that can be attained and the level of staff the hospital management are willing to make available, and the related costs of the different structural or technical fire safety provisions in the building.

The traditional approach focuses on creating fire compartments of a defined maximum area to prevent the fire from spreading further than an appropriate area. These compartments are enclosed by fire resistant walls and floors and self-closing doors. Sometimes, mostly as a trade-off for omitting self-closing doors or compartment size, automatic sprinkler installations are installed to increase the safety level of such a fire safety concept. Timely evacuation is hardly considered at all, since regulations assume that aspect to be covered by limiting travel distances and requiring automatic fire detection in all patient rooms.

In the design process of a hospital measures for fire safety focus only on fire compartmentation and related fire safety measures. The factor of presence of staff (staff-patient ratio), and the performance of staff during evacuation is not taken into account. But research of fires in health care facilities has shown that there is a major role for the staff during an actual emergency. For an integrated approach it is important to incorporate the factor of staff and their role in safely and timely evacuating the ward.

New design ambition

The aim, i.e. to develop a design guideline that helps in implementing an integrated fire safety concept, can be achieved by creating a design tool in which different parameters such as architectural elements, presence of staff and the training of staff can be incorporated[4]. The Required Safe Egress Time of bedridden patients needs to be calculated, who depend on hospital staff during an evacuation. With the new data gathered in the research RSET calculations can be made for different types of hospital wards. The design tool can calculate the time required for this evacuation, assisted by hospital staff.

Because of a lack of data and different factors which are difficult to determine within the scope of this study such as behaviour of patients and the composition of materials present in patients rooms, in the design approach the RSET determined is not directly linked with an explicitly calculated Available Safe Egress Time. Instead of ASET, a simplified "exposure to fire" factor is calculated, with several parameters determining the probability of casualties. The factor is used as the relative risk of casualties on the ward. The reference layout based on the maximum allowable compartment size and other measures prescribed in regulations is assigned a risk factor of 100%.

Parameters that influence the risk value can be selected, such as adding self-closing doors, sprinkler protection, combustible materials restrictions in corridors or the layout of the design and of the emergency exits. Combining these measures will lower the risk factor of the ward.

With gathered data when evacuating specific wards the total evacuation time can be calculated. By comparing the calculated evacuation time with the value for a hospital ward based on the regulations, the effects of different parameters in the design and in the number of staff available to assist in an evacuation can be displayed. The faster an evacuation can successfully proceed, the lower the probability of casualties, determining the level of fire safety of a specific design. With the design tool calculating a relative risk and a total RSET for a new design compared to the ward, fulfilling the demands of the regulations, a more flexible interpretation is possible. A more integrated fire safety concept can be already a part of the design process at an early stage, or can help to make existing hospitals sufficiently safer.

EXPERIMENTS

Research in evacuating different types of patient rooms showed that the time required to evacuate bedridden patients can be significantly higher than previously presumed. Since there was no data available for the actual disconnecting and evacuation times for specific patients, a series of evacuations (experiments) has been performed. The actual times needed to disconnect these patients from all equipment to prepare them for evacuation have been determined as a part of the total egress time per patient, in which the different phases of that total evacuation have been recorded and analysed. Data about the following patients is gathered:

- Basic set up of patient bed;
- Standard patients (for wards such as general surgery);
- Dialysis patients;
- Intensive Care patients;
- Neonatal ICU (incubator) patients;
- Heart monitoring patients;
- Recovery patients.

The experiments were performed by emergency response personnel (trained staff, including nurses) of different hospitals. On every ward the evacuation drill was performed by five couple's separately. Every couple did an evacuation drill of one patient two times, to be able to determine an average egress times for evacuating the specific patient. Different staff members took part in the experiments. The analyses show the differences in disconnecting times per ward per patient, the differences in the total egress time between staff with working experience in that specific ward and staff usually working in another type of ward and staff that is not used to work with patients and the effect training the staff for that specific ward has on the overall performance. The experiments also showed significant increase in performance by staff in the first and the second time they performed the evacuation drill.

Figure 3 & 4. Pictures of the evacuation experiments

All staff members who took part in the experiments were trained for evacuation drills for standard patients, and were all familiar with the evacuation procedures of the hospital. The different parts of the total egress time that have been recorded and data derived are displayed in figure 5.

On every specific ward the patient was connected to equipment which is standard and average for the patients on that type of ward. Some patients on the ward will be connected to more specialised equipment, and some patients to less equipment.. For the evacuation rounds no real patients were used, but random persons of a normal weight. During the evacuation drills there was no verbal communication between the staff and the patient. The data gathered didn't imply the factor of patients who panicked and could disturb the evacuation procedure.

Evacuation procedure
The evacuation times and travel speeds sampled in the experiments of evacuating hospital patient are showed in the figure. The experiments were carried out without actual fire or smoke, as the hospital was in normal operation. Tests are performed by evacuating a single patient room multiple times, eliminating the interference that should be expected when a complete ward is evacuated at the same time. The parameters recorded in ddifferent phases of the evacuation route are:

Staff arrival time
The walking speeds of hospital emergency responders without bed divided by the distance staff need to walk to start with evacuating the first patient, and the time it takes to return to the following patient after evacuating a patient to outside the compartment.

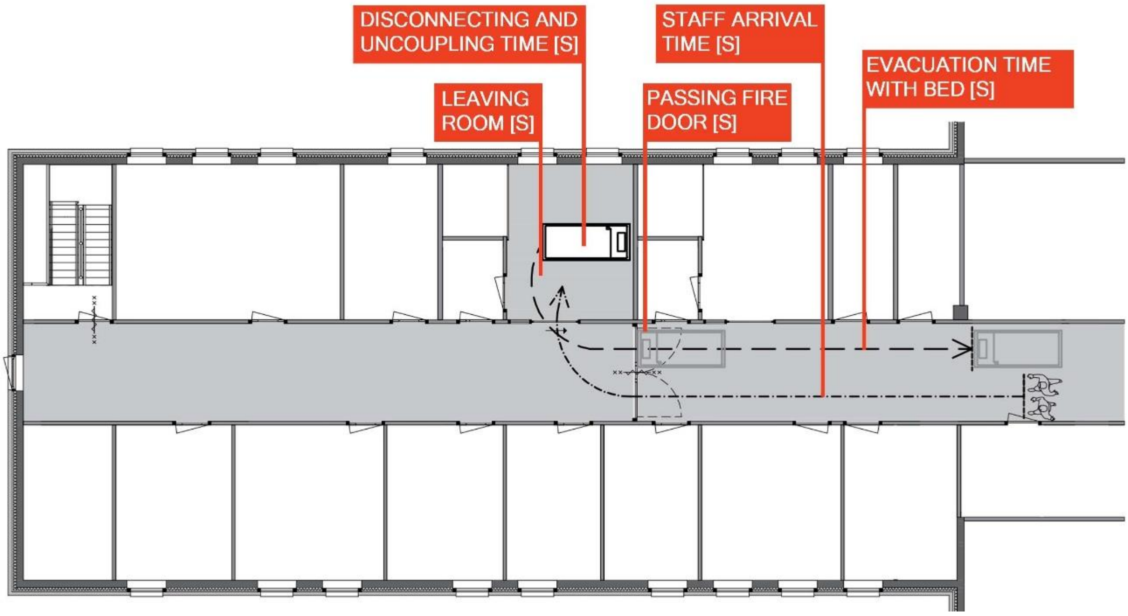
Disconnecting and uncoupling of patients
The average uncoupling and disconnecting times of different categories of patients of different hospital wards. The equipment patients were connected to during the experiments are displayed on the following page.

Leaving room with bed
The time needed for leaving the patient room starting with the bed in its original position and with the patient disconnected from equipment. Even without a self-closing door maneuvering the bed through the door opening takes extra time in addition to leaving with the normal walking speed. The "leaving room" time is only tested for single patient rooms. But because of the complexity of maneuvering a bed out of a room, the effect in time of a larger patient room will be relatively small compared to the single patient room.

Evacuation time with bed
The unimpeded walking speed with bed divided by the distance emergency responders have to cover to evacuate a patient out of the fire compartment.

Passing fire door with bed
The time needed to pass a fire door with a bed is measured separately, because of the added complexity due to the self-closing mechanism.

Figure 5. Different parts of a tested evacuation route



During the experiments the data for disconnecting patients on different types of ward is gathered. Patients were connected to the equipment regular for the ward involved. Patients were connected to the following equipment per ward:

Table 1. Equipment patients were connected during experiments

	Basic patient	Regular patient	Dialysis	Recovery	Heart monitoring	Neonatal ICU*	Intensive Care*
Disconnect power plug of bed and release brakes	1	1	1	1	1	1	1
Oxygen supply connected to wall	-	1	-	1	-	1	1
Intravenous drip	-	1	-	1	-	-	1
Catheter	-	1	-	-	-	-	1
Syringe pumps	-	2	-	-	-	2	6
Dialysis equipment	-	-	1	-	-	-	-
Monitor	-	-	-	1	-	1	1
Bear hugger	-	-	-	1	-	-	-
ECG monitor	-	-	-	-	1	-	-
Saturation sensor	-	-	-	-	1	-	-
* During evacuation, specialised staff needs to choose which equipment can be disconnected and whether the patient can safely be evacuated at all.							

Results

Measured uncoupling times are displayed in the table below. There are substantial differences between the wards in how long it takes to uncouple the patients. The number of samples is noted between brackets.

The experiments also showed that there is a difference in the time required for uncoupling during the first and the second round. During the first round all staff was searching for what to disconnect, and in which order. When they performed their second round right after the first round, even inexperienced staff achieved much faster uncoupling and disconnecting times. We conclude that if staff is regularly trained with disconnecting patients on different types of wards, faster egress times of hospital wards can be achieved (as shown in table 2).

Table 2. Disconnecting times of specific wards

	Basic patient (10)	Regular patient (10)	Dialysis (10)	Recovery (10)	Heart monitoring (10)	Neonatal ICU (10)	Intensive Care (10)
Average of first round [s]	6,6	33,4	17,8	35,8	44,0	62,8	109,8
Average of second round [s]	4,4	28,0	12,8	21,2	23,0	29,2	68,6
Total average [s]	5,5	30,7	15,3	28,5	33,5	46,0	89,2
Standard deviation [s]	1,78	7,56	4,60	14,07	16,79	24,07	24,45

The general parts of the evacuation, such as approaching the room, evacuating with the bed, and passing a fire door with a bed are combined in the table 3. The time for leaving a patient room with a bed is also determined. All patient rooms used were single patient rooms and there can be differences with patient rooms for multiple patients, where there is maybe more space to manoeuvre.

Table 3. Egress times of specific parts of evacuation

	Arrival speed [m/s] (70)	Leaving room [s] (60)	Evacuation speed with bed [m/s] (70)	Passing fire door [s] (30)
Total average	1,42	9,3	1,23	7,4
Standard deviation	0,27	3,51	0,62	2,13

Important observations

If staff is not used to perform the evacuation procedures, it is likely that delays occur during evacuation. The experiments showed that if staff doesn't know exactly what to do, time is lost in coordinating between the different staff members. With more training this delay can be minimised.

The influence of the level of evacuation training of staff could be evaluated from the experiments performed on the specific wards.

The results showed a large effect of training of staff, as major improvements can be seen in the uncoupling time between the first and second round. Some further improvement can reasonably be expected with additional training rounds.

Figure 6. Influence of staff training

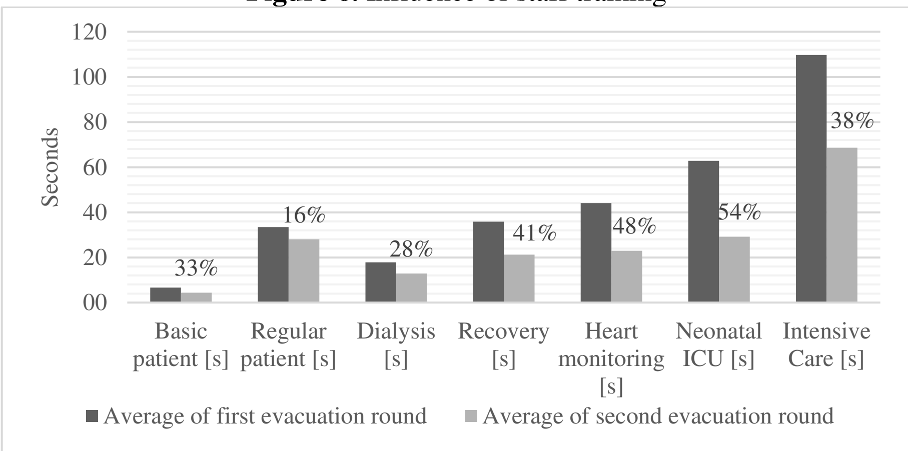
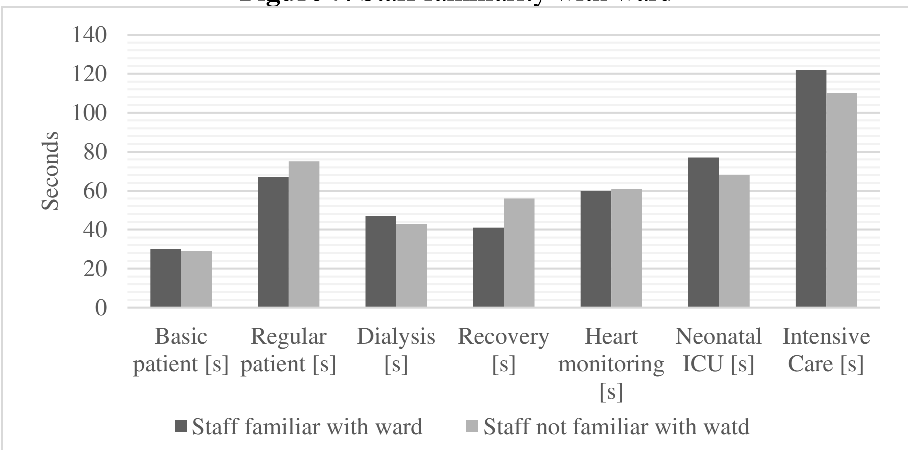


Figure 7. Staff familiarity with ward



The effect of the level of familiarity of staff with the ward and the equipment is evaluated based on the experiments for the specific wards. The amount of experience of working with the equipment of the evacuation couples differed. Staff with working experience on the ward as well as staff unfamiliar with the equipment of the ward, must be able to contribute to an evacuation of all types of wards without unnecessary delays. The results show that there are only small differences between staff who are common to work with the equipment of the ward, and staff who are not familiar with the ward. These differences in results can be explained by the basic knowledge of the equipment of all staff working at hospitals.

DESIGN APPROACH

The data gathered during the experiments was used in creating a new design tool to create fire safe hospital wards. The design tool can compare different type of hospital wards, both for existing as new designed hospitals.

RSET calculations

An important factor in the total evacuation time is the number of staff available to assist in the evacuation. In calculations the staff of different wards can arrive after predetermined time to assist during evacuation. Especially in evening or night situations the strategy of hospitals is to let staff of other wards come to the ward in case of a fire alarm to assist the evacuation. The experiments showed that all hospital staff can contribute more or less equally efficiently to the evacuation on a specialised ward.

The RSET calculations are only made for bedridden patients, because they need assistance during evacuation. It is not sensible to make evacuation calculations for patients using standard calculation tools, only based on slower walking speeds. Bedridden patients must be assist during evacuation. In the first place they must disconnect the equipment, then they have to evacuate the patient with the bed to one of the exits of the ward. Most hospitals choose for this strategy, they don't want patients to walk to the exit of the ward or fire compartment by themselves even if they are physically able to do so. Patients are disabled and it's is not sure at which pace they can exit, and there is a large chance of fainting. Hospitals do not want disabled and possibly fainted patients to spread through a smoke filled hospital ward.

To make a realistic RSET calculation of a ward, the response time and possible extinguishing attempt have to be incorporated. After a fire alarm is activated staff have to respond, establish the location of the fire, and assess what to do. Most hospital staff is trained in extinguishing small fires. When it is not possible for the staff to extinguish the fire, they have to evacuate the ward as fast as possible. The response time of staff is very variable, and has not been part of this research. The data has focused on the actual evacuating time per patient. How the design tool calculates the evacuation time per ward is merged in the following equations.

The evacuation time per patient can be calculated as follows:

Evacuation time per patient = (Arrival distance [m] / Arrival speed [m/s]) + Uncoupling time [s] + Leaving room [s] + Passing fire door [s] + (Evacuation distance [m] / Evacuation speed [m/s]) [1]

With the evacuation time per patient the RSET of the ward can be calculated as followed:

Average RSET of ward = (Response time [s] + Extinguish attempt [s] + (Evacuation time per patient [s] x Number of patients)) / (Staff present + (Extra staff – arrival time [s]) + (Extra staff – arrival time [s]) + (…)) [2]

With the data gathered the evacuation time per ward can be calculated. By using the same data for calculating new designs of wards, the difference made by smaller compartment sizes or extra staff can be identified. With the same data used in calculations, different types of lay outs can be compared.

Relative risk analysis

In order to couple calculated RSET values to fire safety measures required to allow safe evacuation, a simple model was developed that combines a variety of fire safety measures to a calculated relative risk on casualties and damage for a ward. Data of the ASET to make a direct link with the RSET have not been part of the scope of this study. But with the risk analysis additional fire safety measures can increase the safety of present patients, and the probability of loss of the building can be reduced. The design tool calculates the assumed effect of a fire in a patient room on the entire ward. The results show how fire safety measures can prevent casualties and reduce the total damage.

The design tool calculates the risks based on an event tree analysis. In this analysis the annual probability of igniting a fire in a hospital is included. This probability is based on a formula which combines the surface area of a fire compartment and the expected frequency of a fire occurring in the specific fire compartment per square meter of surface [5]. With the annual probability of igniting a fire, the effect of fire safety measures on the risk can be calculated. An estimate of the failure probability for each fire safety measure is incorporated. The results show a percentage difference in both the risk of casualties and the risk of damage for the new design compared to a reference layout based on the regulations. With this difference expressed as a percentage wards can be compared.

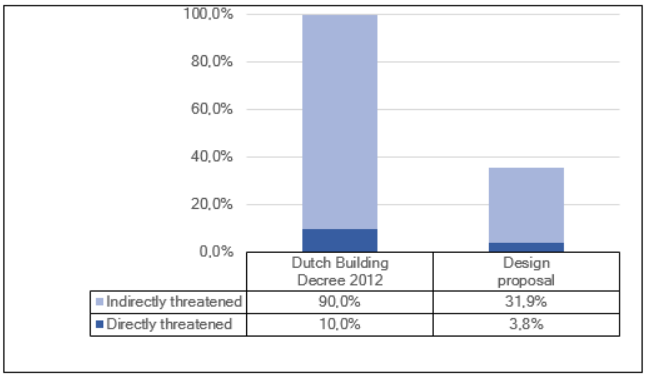
This reference layout per ward, is the maximum size allowed by regulations, both for new hospitals as for older hospitals. With this analysis different alternatives can be analysed to show the impact of additional fire compartmentation, or automatic extinguishing systems. This also offers the possibility to calculate how and at what costs older hospital wards can be upgraded to obtain the level of safety intended for new hospitals.

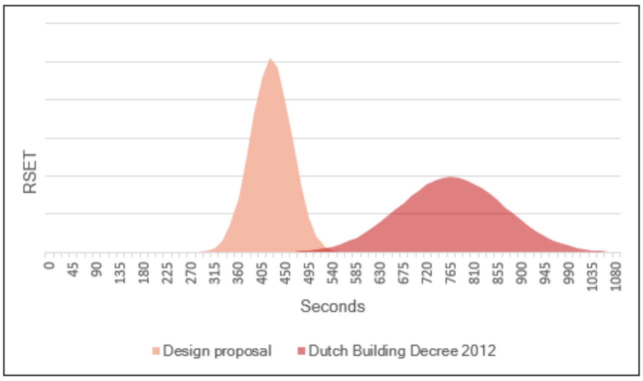
By further subdividing the ward in protected fire compartments, the risk of casualties and loss will decrease. The event tree per level of fire compartment separation designates a probability of failure. The design tool assumes the fire in the largest patient room, these patients are directly threatened. A distinction has been made between directly and indirectly threatened patients. Directly threatened patients are patients who are in the same sub fire compartment as the assumed fire. Indirectly threatened patients are patients who are in a ward with sub fire compartment separations. These patients are not direct exposed to the fire, but have to be evacuated as soon as possible since the sub fire compartmentation offers protection for a limited time only.

Design strategy

The figures below display the output of the design tool. To evaluate the actual effect of proposed fire safety measures, it is important to determine a starting point . This starting point can be used as reference for design improvements. This starting point can be the existing ward, or for new hospitals a ward which can be designed on the maximum allowable compartment size of the regulations.

Figure 8 & 9. Comparison of risk analysis and RSET calculations





The RSET can be compared with a reference layout based on the regulations. If the RSET fulfils the requirements of the regulations, but is still rated as too long by the hospital management, measures can be taken to shorten the evacuation time. The ASET is interpreted with an risk analysis model, because there was not enough reliable data available to calculate an absolute value for the available egress time.

By calculating both an required egress time, as the relative chance on casualties and damage, insight is created in the effectiveness of measures. Because there is no collateral of the actual egress time of probability of a fire occurring, the effectiveness of a measure can be obtained by the percentile change. With the cost of the measures or the cost of extra personal, a comparison between costs and risks or evacuation time can be made. Hospitals can decide if the investment cost is overridden by the reduce in risk or decrease of evacuation time.

Practice
To clarify how the design tool can work, and its advantage, a fictitious example of a hospital ward is analysed. This ward is a common ward, as is often incorporated in existing and newly designed hospitals. The ward has a variety of patient room sizes, which is common for existing hospitals.

The ward is calculated both as standard hospital ward, with a disconnecting time of 30,7 seconds per patients, and as Intensive Care ward with an disconnecting time of 89,2 seconds per patient. We suppose that two staff members are already present on the ward, who can directly start the evacuation. Extra staff members present on other wards in the hospital contribute to the evacuation, taking into consideration their arrival time to the ward. With these starting points the total evacuation times are calculated.

Figure 10. Example of hospital ward in existing hospital (12 patients in total)

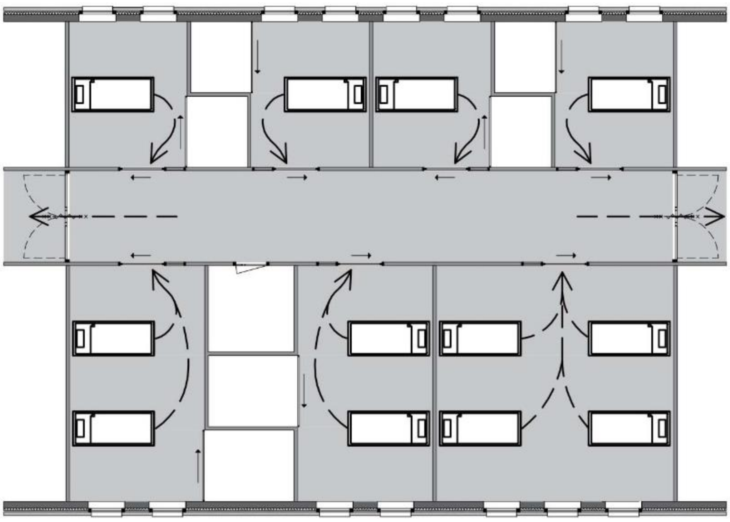


Table 4. Calculated RSET per ward

	Standard hospital ward		Intensive Care ward	
Staff member performing evacuation	Evacuation time [mm:ss]	Reduction [%]	Evacuation time [mm:ss]	Reduction [%]
2 staff members	14:20	-	29:12	-
2 staff member + 2 extra staff members after 1 min.	07:35	47%	15:43	46%
2 staff member + 2 extra staff members after 1 min. + 2 extra staff members after 5 min.	05:48	60%	12:14	58%
4 staff members	07:10	50%	14:36	50%

Table 5. Calculated risks per ward

	Risk of casualties [%]	Risk of damage [%]
Ward based on regulations	100 %	100 %
All patient rooms sub fire compartments	68 %	70 %
All patient rooms separate fire compartments	64 %	66 %
Risk reduction in corridor	46 %	58 %

The evacuation time of the same ward with Intensive Care patients is almost twice as long as the same ward with standard patients. In order to eliminate this difference, the hospital could opt to double the staff:patient ratio of the Intensive Care ward. Another option in an early design phase is to make sure the IC is located centrally in the hospital, such that extra staff members can arrive to the ward much faster. With two extra staff members after 1 minute, and two more staff members after 5 minutes, the total evacuation time of the IC is already shorter than the standard ward with normal staffing.

The risks can be reduced by creating fire resistant separations between the patient rooms, or by increasing the fire resistance level of separations between patient rooms and fire compartments. This reduces the probability of casualties, and also decreases expected damage compared to a ward based on the regulations. The risk can even be more reduced if the possibilities for ignition in the corridor are eliminated. It can be a choice to take the latter measure only for the Intensive Care ward, since the evacuation time of this ward is sufficiently longer. The analysis is not intended to increase the risk if the evacuation time is decreased in a percentile comparison. Such comparison would not be valid.

CONCLUSION

The designs of hospitals are based on too optimistic estimates of evacuation times. The regulations governing current hospital design are in this respect outdated. A large variation was observed in uncoupling times per patient on different types of ward, where currently these patients are approached the same in egress calculations and strategies. Bedridden patients are totally depended on staff when a fire occurs and the patients need to be evacuated. Equipment should be disconnected by staff and patients must be transported in bed to the exits of the ward, which is in most cases the fire compartment.

The results of the experiments show that there is a big difference in the uncoupling times between different types of wards. This uncoupling time per patient will have a big influence on the total egress time of a ward, especially when multiple patients are present in one fire compartment. The actual uncoupling time and total evacuation time per patient should be considered in designing hospital wards. There are big differences in the behaviour of staff and their evacuating speed. More training can ensure faster evacuating times. If all hospital staff is regularly trained and familiarised with equipment, all staff who perform as emergency responders can contribute to a fast evacuation. The experiments gave more insight in the actual behaviour of staff, and important observations of influences on the required egress time of a ward.

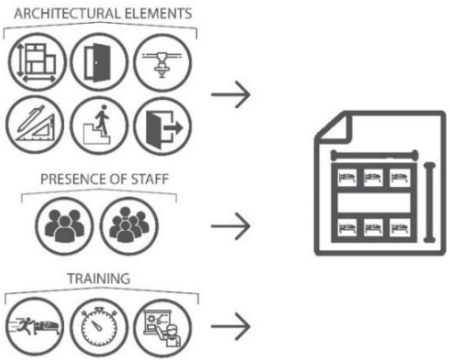
With the changing design trends in hospitals, more fire risks are introduced which lead to a lower ASET. With more required care per patient in hospitals, the RSET increases. In some cases we suspect that the safety margin between ASET and RSET may become too small. Measures such as hospital design taking into account the differences between wards, and increasing the level of training of emergency responders, will contribute to reversing this trend.
If hospitals approach the fire safety problems with a more flexible design strategy, they have more freedom to design for different types of wards, and the effectivity of the measures they choose to reduce the risk. Different types of wards can be compared on the same level of fire safety. The design tool shows to be a useful tool to compare the different options to optimize the fire safety level of hospital wards.

The design for different hospital wards with this approach can be more flexible and integrated, compared with the regulations that are basically focused on demands about the maximum allowable square meters. With the design tool, hospitals can make a financial consideration between investing in adjustments on the building level, or choose to invest more in staff support.
The design tool calculates a relative risk of casualties per design of a ward, which fits in a fire compartment. With adding different probabilities, the risk value can be determined. In the design process, it is possible to change or add probabilities, such as adding self-closing doors. These parameters will decrease the relative risk on casualties on ward.
In the approach the ASET is not absolutely calculated in terms of time, because of a lack of data about actual fires in hospitals. Therefore an risk analysis model is created which calculates the relative risk of casualties and damage per ward.

But with the data gathered a specified RSET can be calculated for specific wards in the hospital. By comparing the calculated evacuation time with a hospital ward based on the regulations, the effects of choices both in the design but also in the number of staff present to full fill an evacuation can be displayed. How faster an evacuation can be successful proceed, the lower the chance on casualties.

However, it is a requirement that staff in hospitals has already achieved a certain training level to proceed fast evacuations. When the staff is already trained the calculated RSET can be achieved. By using the design tool in practice the advantages are clear. By indicating both the percentile change of decreasing the RSET, as a percentile change in reducing the risks of a fire both can be compared, but not eliminated against each other. Such comparison is not intended and would not be valid. The different parameters of the design tool can be variably used, with comparable results focussed on the percentile change.

Figure 11. Different parameters of new design approach



Further research can focus on gathering more data about uncoupling times of specific patients. More gathered data will be necessary to have a more reliable average values of the evacuating times. The standard deviation of a RSET calculation can be defined more precise when more research will be performed. Also, other parts of the evacuation route can be further investigated.
For further development of the the approach more data about the causes of fires in hospitals is necessary, and more insight in the actual risk of fires and their consequences. If there is more insight in actual fires in hospitals, the ASET part of the approach can be further elaborated. With a wider spectrum of data and knowledge an actual estimation about the available egress time can be made, and with that the probability of a successful evacuation of an entire hospital ward.

By approaching the fire safety in hospitals with a more flexible design strategy, hospitals have more freedom in designs for different types of wards, and the effectivity of the measures they choose to reduce the risk. With directly implanting the number of staff members who can proceed an evacuation and their arrival time in the design, the desired connection between adjustment on the building and the organisation of staff is made. The method is already used in practice in two different hospitals and has proved its effectiveness. Hospitals can make a financial consideration between investing in adjustments on the building level, or choose to invest more in staff support.

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