Methodology to determine the adequacy of indoor enclosures to use infrared thermography cameras and their application to medical emergency services

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Abstract

When an infrared thermography camera is used inside buildings, the characteristics of the place where the camera is used should be considered since results could be affected. For this reason, the development of methodologies is of great interest to know, as accurate as possible, whether these spaces have the appropriate conditions to use those cameras. The goal of this research is to establish the possibility of applying quality management methodologies, such as the Quality Function Deployment, very known and usually used in other scopes. Thus, the characteristics of enclosures belonging to medical emergency units in Spain were used as the object of experimentation given the importance of these services for society and the possibility of using directly useful technologies for diagnosis. After collecting the starting information based on references, the consultation to 21 experts, and the characteristics of these enclosures included in regulations, standards and recommendations in Spain, and also after applying the methodology mentioned above, the results showed that air conditioning (13.6/100), the thermal insulation of the room (11.9/100), windows (10.5/100), dimensions of spaces (10.2/100), and humidity (10.1/100) are the most influential factors. Within the scope of medical emergency services, those triage, consultation, examination, treatment, and observation rooms fulfilling what is specified by Spanish regulations, standards and recommendations obtained positive assessments (≥3/5) in most cases. It was therefore concluded that this methodology is of great interest to assess generally the suitability of indoor enclosures to use infrared thermography cameras, and regarding the specific case of the main enclosures of medical emergency services fulfilling with Spanish standards and recommendations, their characteristics make them suitable for using infrared thermography cameras, at least in relation to the fulfilment of basic conditions.

Keywords: ThermographyAdequacy of indoor enclosuresQuality Function Deployment (QFD)Medical emergencies.

1. Introduction

The use of infrared thermography cameras inside buildings is usual in many scopes [1], [2]. In these cases, the characteristics of the place or environment in which the camera is used could affect, sometimes considerably, the results and even make them erroneous [3]. For this reason, methodologies to establish systematically whether these spaces have acceptable conditions are required so that the distortions mentioned above are not produced by using these cameras. Based on these aspects, the goal of this research is to establish the possibility of assessing those conditions by using the application of the Quality Function Deployment (QFD), which is original in this field. To experiment with this methodology is advisable to use standardised enclosures where the use of infrared thermography cameras is referenced in the respective scientific literature, such as the case of medical emergency services. This selection is based on the numerous research studies related to the use of infrared thermography cameras in medicine [4], [5], [6], [7], [8], applying in some cases standardisation methodologies [9] or protocolization [10], and particularly on the specific studies where these cameras are used for medical emergencies [11], [12], [13], [14]. So, infrared thermography should often be used in these emergency services nowadays, at least in the first moments of patient care. However, the medical staff sometimes considers, erroneously in our opinion, that these technologies are hardly feasible to be used in these spaces and they think that it is more appropriate to use other means of diagnostic imaging (Magnetic Resonance Imaging, ultrasound, X-ray, among others). However, according to references [4], [5], [6], [7], [8], [9], [11], [12], [13], the use of an infrared thermography camera could be strongly useful in the evaluation of patients, both in the triage and in the consultation or corresponding examination. On the other hand, taking into account the definition of medical emergency [15], a research gap was found regarding systematic, fast and efficient methodologies to assess the suitability of the medical care units of any emergency service to perform thermal imaging [16]. For this reason, the QFD Methodology was experimented in these spaces to know the possibility of using this methodology to determine systematically the fulfilment level of the most acceptable conditions, so that erroneous results are not produced by using infrared thermography cameras.

2. Methodology

The methodology was developed by following the steps included in Fig. 1. The first step was focused on the compilation of theoretical knowledge regarding two aspects: (a) the fundamentals of infrared thermography and its applications; and (b) the existing systematic methodologies to evaluate the quality of products and processes, according to certain conditions. This theoretical knowledge of infrared thermography has already been extensively reviewed by various works, highlighting the compilation published by Vollmer [17]. In this sense, it should be noted that the scientific literature analysing the various factors which influence the results of infrared thermographies applied to humans was highly useful for this study. Here, the exhaustive classification made by Fernández-Cuevas [3] should be highlighted. It is also worth mentioning the checklist entitled ‘Thermographic images in sports and exercise medicine (TISEM)’ by Gomes Moreira [18], [19], the documentation generated by the International Academy of Clinical Thermology (IACT), and the ‘Standards and Protocols in Clinical Thermographic Imaging’ [20]. Considering these references, Table 1 presents a compilation of the factors most affecting the result of the infrared thermography applied to human beings.

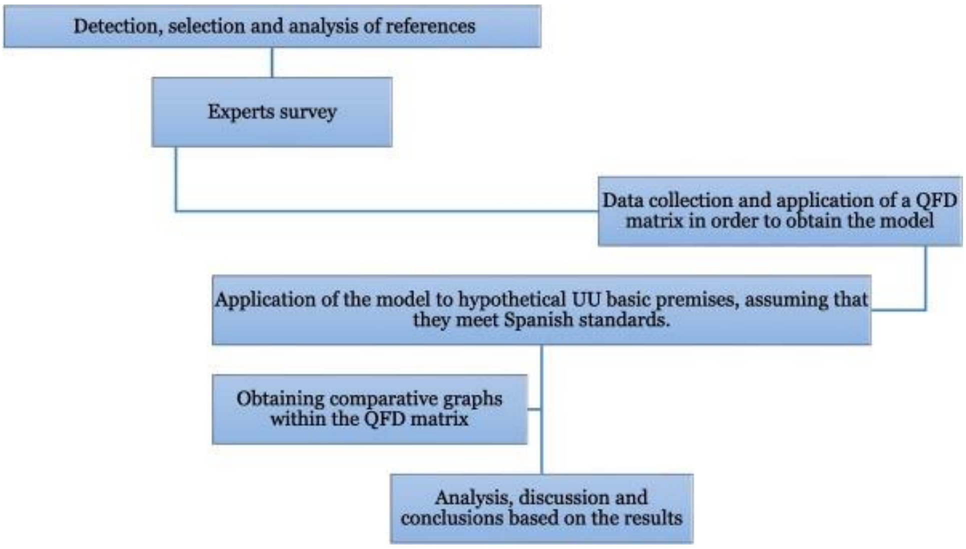

Fig. 1. Diagram of the steps taken to develop the research methodology.

Table 1. Compilation of the most important factors which could affect the result of the infrared thermographies applied to human beings (based on [3]).

Environmental factors	Individual factors		Technical factors
Related to the place.	Related to the patient evaluated and their characteristics (influence of skin temperature).		Related to the equipment used.
–Room size	**Intrinsic**	**Extrinsic**	**–Validity**a)
–Room temperature **–Relative humidity (RH)** **–Atmospheric pressure** **–Radiation sources**	Gender, age, anthropometric issues (height, weight), heart rate, hair density, skin emissivity, medical history, metabolic rate, skin blood flow, genetics, and emotions, among others.	Related to: intake (pharmacological treatment or drugs, alcohol, tobacco, tea or coffee, food, drinks-hydration); substances applied to the skin (ointments and cosmetics, water); solar radiation; certain therapies; recent physical activity (perspiration, training level, symmetry, and specialisation, among others.)	**–Reliability**b) **–Protocol** **–Distance** **–Background** **–Position of the camera** **–Resolution** **–Temperature range**

Environmental factors	Individual factors	Technical factors
		–Camera calibration and testing **–Software** **–Selection of regions of interest (ROI)** **–Statistical analysis** **–Other characteristics of the camera**

a) Accuracy: the measurement corresponds to reality.

b) Same result in repeated measurements.

Frequently, in the case of vital emergencies, it is not possible to choose, control or modify the individual factors of the patient to be surveyed using infrared thermography. On the contrary, environmental and technical factors can usually be controlled. For this reason, this study is focused on the latter, assuming that the camera has a valid calibration certificate and appropriate characteristics, at least those specified in Table 2.

Table 2. Minimum features that infrared thermography cameras should fulfil to not constitute an influence factor.

Features	Values	Comments
Measurement range	20–50 °C	Adjustable
Spectral range	7.5–14 µm	
Thermal sensitivity	<0.08 °C	A camera of considerable accuracy and thermal sensitivity (minimum of 80 mK) is required to differentiate very similar heat levels, especially when appreciating changes, sometimes subtle, in the cutaneous surface [21]
Accuracy	<1 °C ± 1.00%	
Absolute resolution	>768,00 pixels	Cameras with at least 320x240 pixels are normally used [3].

Features	Values	Comments
Lens-objective-angular	15–25 – 45°	Lenses are chosen depending on the distance and the area to be thermographed [3].
Manual focus	Manual or semiautomatic	Color palette, backlight, image mode, type of recording, emissivity, reflected temperature, distance, relative humidity, and atmospheric temperature, among other.
Camera options: parameter settings and connection to specific software for medical thermography.		Having an efficient, easy-to-use software that provides the greatest amount and as much quality as possible of data is essential in medical emergencies.

On the other hand, as the objective is to assess the suitability or quality of the places where the thermography is carried out, the application of a quality assessment methodology, such as the QFD, was appropriate to fulfil this objective. As for the theoretical knowledge of the QFD, it is widely developed in the corresponding literature, including compilations such as those made by Chan and Carnevalli [22], [23].

For the application of the QFD, both the experience of the authors of this paper and the results of the surveys with 21 experts were also necessary. Fig. 2 shows the characteristics of the experts consulted and the proportion according to the number of participants of each characteristic group with respect to the total.

Fig. 2. Group classification, according to their characteristics, of the experts consulted, and the percentage proportion is indicated according to the number of participants which belongs to each group with respect to the total.

In addition, the SEGRA (Spanish Society of Graduates in Radiology) was also considered.

This experts survey was conducted via face-to-face, by telephone and/or through questionnaires as that included in Fig. 3.

Questionnaire

The experts were asked to rate from 1 to 10 (1 was the minimum importance and 10 the maximum) the influence of the factors indicated below on the final result of the thermographs:
-Room dimensions.
-Room temperature.
-Time to acclimate the patient.
-Ambient humidity.
-Atmospheric pressure.
-Absence of other sources of radiation (heat) in the room or nearby.
-Precision and sensitivity of the thermal imager.
-Training of the staff conducting the thermography and reporting.
-Existence of action protocols.
-Adequate distance from the camera to the patient.
-Absence of nearby reflective elements.
-Positionable camera in different angles.
-High camera resolution.
-Camera adjustable to a human temperature range.
-Cleaning of the body area to be thermographed.
-Adequate lighting of the room.

***Other possible factors** and their importance from 0 to 10.*

Means and equipment that should be available in the units conducting this type of testing, and factors affected.

Other comments:

Fig. 3. Example of the content and structure of the questionnaire for experts.

Based on all the above aspects, the QFD methodology was therefore applied by constructing the matrix called 'House of quality' on the QFDonline tool. In this matrix, the collected data were firstly introduced as the so-called '*Whats'* (demanded quality) with their corresponding weights (weight/importance: 0–10), and 'Hows' (Quality characteristics) and their relationships: ⊝ "Strong Relationship"; ○ 'Moderate Relationship'; and ▲ 'Weak Relationship'.

Possible interactions or positive and negative correlations were also included between the 'Hows': "Strong Positive Correlation" (++); "Positive Correlation" (+); 'Negative Correlation' (−); and 'Strong Negative Correlation' ▼.

In the 'Direction of improvement' section, the trends of each 'Hows' and those corresponding to the difficulty of fulfilling them were indicated. The 'Hows' were evaluated as follows:

$$Result - Weight\ of\ \text{'how'} = \sum_{What} (Weight\ of\ each\ \text{'what'}) \times (Correlation\ coefficient) \quad (1)$$

Since not all 'Hows' are equal, that is, not all have the same probability of success due to their different difficulties, the corresponding coefficient (coeff.) of difficulty was added in the forms:

$$A.S.\text{'how'} = \sum_{What} (Weight\ of\ each\ \text{'what'}) \times (Correlation\ coeff.) \times (Difficulty\ coeff.) \quad (2)$$

$$R.S.\text{'how'} = \frac{\sum_{What} (Weight\ of\ each\ \text{'what'}) \times (Correlation\ coeff.) \times (Difficulty\ coeff.)}{\sum_{x-How} x \times \sum_{y-What} y} \quad (3)$$

where A.S. 'How' is the absolute score of 'How' and R.S.'How' is the relative score of 'How'.

Once the relative or important weights of each 'How' were ascertained, they were applied to the characteristics of the different areas of an unit of emergency (EU), according to the existing Spanish standards. Finally, the results were classified, analysed and interpreted.

3. Results

Based on the references and the consultations with experts, Table 3 presents the influence factors, observations and assessment (from 0 to 10) of each. These observations and score assignment only show those which, according to the configuration of a classic QFD matrix, are useful to develop this matrix regarding the objective established.

Table 3. Influence factors selected, including observations and assessment (from 0 to 10) of each factor based on the references found and the consultations for experts.

Factors	Observations related to the construction of the QFD	Weight (0–10)
Available space, features and equipment.	The experts considered as necessary a minimum size (approximately 6–10 m2 or between 2 × 3 and 2 × 5 m, with no very high ceilings) [3], [24], [20] that allow mobility for work and for the patient, thus maintaining an adequate distance [20]. It was also considered the existence of a work table, together with usual building services (electrical sockets, artificial lighting, etc.), a water tap with sink, a stretcher with wheels, multi-positionable chairs with footrests, a private area for getting undressed and resting, and a comfortable space for acclimatization [3], [24].	Dimensions: 8 Furniture: 7 Building services: 6 Spaces: 6
Stable and adequate ambient temperature.	In most references, a temperature range between 18 and 25 °C is suggested [3]. However, the experts recommended maintaining a temperature between 21 and 23 °C, with certain adjustments according to the objective of the test: between 22 and 24 °C for extremities, and 20 °C for inflammatory lesions, among others, [3], [24]. In addition, an accurate and visible indicator of the ambient temperature was necessary, as well as the spaces where air currents are avoided and the temperature is stable and homogeneous, regardless of the circumstances. In these cases, it was also noted that a high level of thermal insulation of the room was extremely helpful [3].	9
Acclimation time.	There was no consensus on what would be the most appropriate exact time; a lapse between 10 and 20 min was frequently recommended [4], [3], [24].	Included in the space and temperature section.

Factors	Observations related to the construction of the QFD	Weight (0–10)
Stable and adequate relative humidity.	Relative humidity could influence the results, especially if it is deposited in the form of water on the skin, thus influencing the temperature of its surface. Most research studies were carried out with relative humidity between 40 and 70% [3]; however, the experts considered that the percentage should be between 40 and 60% by installing humidity control equipment and visible indicators.	6
Atmospheric pressure.	The experts did not consider the atmospheric pressure too important, although they related it to temperature and humidity. It is necessary to indicate that this aspect is hardly studied [3], although there is a research which considers it influential [25] and recommends the existence of at least an indicator of atmospheric pressure in the room.	5
Absence of other sources of radiation.	Coincident results were obtained in considering that any external radiation source could influence. Although adjustments could be made to correct this effect, the place where the thermographic capture is made must be isolated and free of such sources (windows, heating elements, water pipes, and air flow, among others).	7
Room lighting.	The experts indicated that current lighting systems do not usually radiate heat (fluorescents and LEDs, among others) when the internal room is not lit up by sunlight (see previous factor), so this factor is not very influential.	Included in the temperature and radiation section.
Absence of air currents.	The experts agreed on the importance of absence of air currents, especially if these affect the patient's body and/or vary the ambient temperature.	Included in temperature section.
Reliability by repetition.	It is a factor related to the verification that the same result occurs in measurements repeated over time.	Included in the protocol section.
Training, experience and protocol.	All experts, the authors of this paper, entities [20] and reference associations such as the European Association of Thermology agreed that there are multiple possible deficiencies due to the lack of training, experience and protocols. However, given the	–

Factors	Observations related to the construction of the QFD	Weight (0–10)
	authors' interest in physical equipment, it will not be the aim of this study.	
Distance from the camera to the patient (2.5 m maximum).	Although the field of view (visible area) depends on the lens of the camera (at a lower distance, the resolution is usually higher), both references and experts indicated the need for suitable lenses for distances between 0.25 and 2.50 m.	Included in the space section.
Background without reflective areas.	There are some significant studies [3] on the influence of different background surfaces. The reflection (ρ) of the thermographed body is not considered in this study, since the measurement of surfaces with high emissivity such as human skin ($\varepsilon = 0.98$) yields significantly low reflection. The reflection can be calculated as per $\rho = 1 - \varepsilon$.	7
Thermography from the most appropriate angle.	References recommends certain angles when taking thermographies [3]; different camera positions can also correct survey errors. Concerning the emergency spaces, it is also recommended in the infrared survey to follow a semicircular path surrounding the patient with a maximum distance radius.	Included in the space section.
Absence of reflective objects.	The removal of watches, bracelets, necklaces, jewelry, etc., as well as their collection and custody, were also indicated as good practices by references and experts.	5
Cleaning of thermography zones.	The existence of equipment to clean and dry the skin (there should not be moisture as it could absorb heat) were also given certain importance, except in the case of some substances in the enhancement of the contrast [26].	Included in the protocol section.
Other factors.	Considering the objective of this research, no other factors have been considered.	

Based on these data, the QFD matrix was constructed by using the QFDonline template, whose results are represented in Fig. 4. This matrix is called 'House of Quality'.

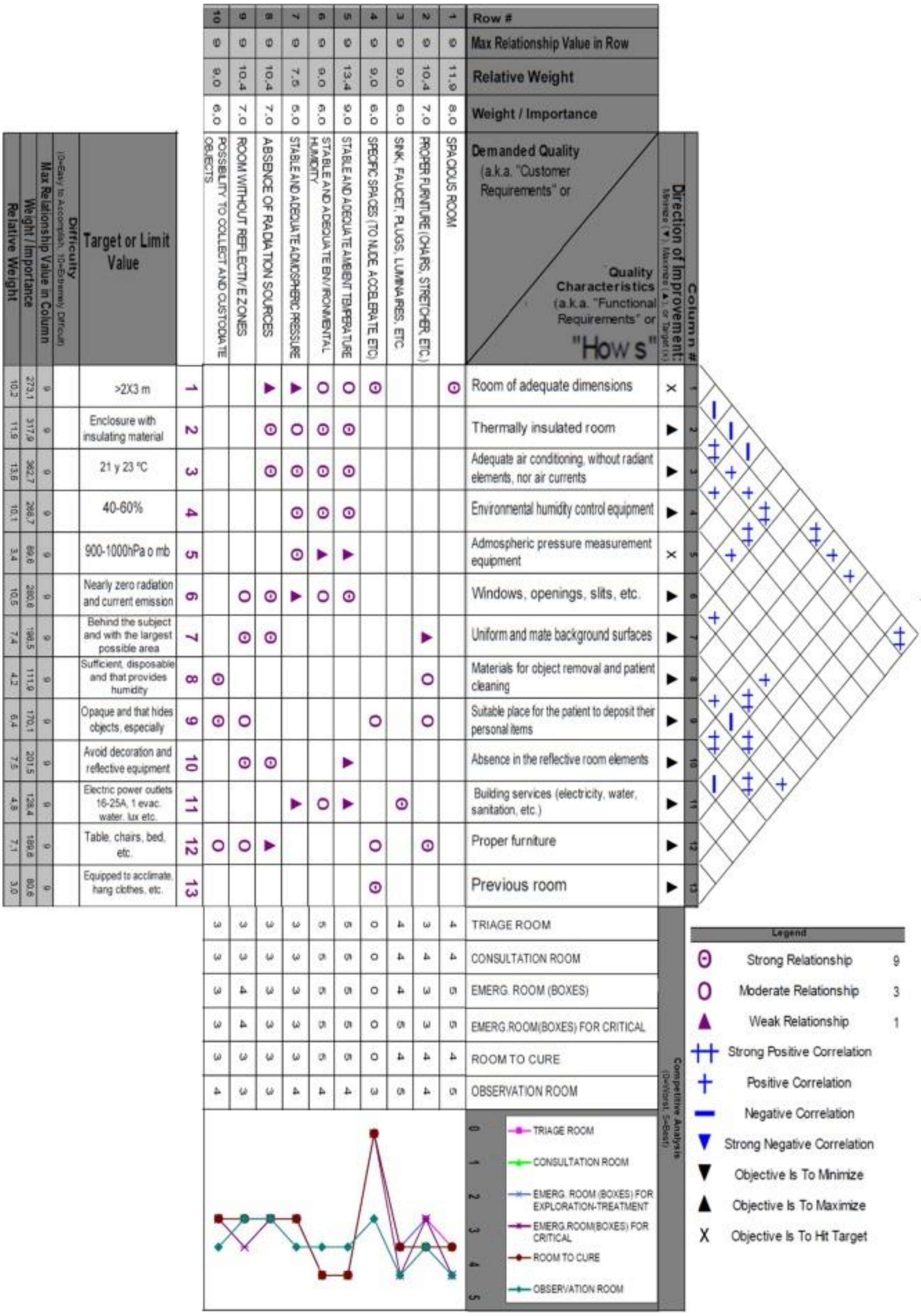

Fig. 4. Final matrix with QFD results based on the QFDonline.

Regarding the meaning of results, the relationship between the ‘whats’ and ‘hows’ (Fig. 5), that is, the relationships between the qualities demanded in enclosures and their characteristics, both experts and references stated strong relationships between the ‘whats’ and ‘hows’ generally when there was a common object, an issue which is obviously unnecessary to analyse. It is of greater interest to pay attention to those ‘hows’ with more boxes marked with a medium or high importance or weight than the ‘whats’.

In this regard, the air-conditioning of the room and its thermal insulation, which is very related to temperature, humidity, radiation sources and even the atmospheric pressure, are first stressed. However, the last factor (the atmospheric pressure) should not be considered as a crucial influence, as comments included in Table 3 and that reflected in the boxes corresponding to temperature and humidity show. In addition, Fig. 5 shows other ‘hows’ related to several ‘whats’ with a medium or high force or importance, such as the case of furniture, item deposit, gap insulation or dimensions of the room. In most cases, these four ‘whats’ were the result of the avoidance of radiation sources, either reflective or light, which obviously should be considered, but, unlike temperature and humidity factors, could be easily controlled by a simple ocular inspection without the need of using equipment; however, equipment are necessary in the case of factors related to air conditioning.

				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	▲	▲	▲	X	▲	▲	▲	▲	▲	▲	▲	▲
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Room of adequate dimensions	Thermally insulated room	Adequate air conditioning, without radiant elements, nor air currents	Environmental humidity control equipment	Admospheric pressure measurement equipment	Windows, openings, slits, etc.	Uniform and mate background surfaces	Materials for object removal and patient cleaning	Suitable place for the patient to deposit their personal items	Absence in the reflective room elements	Building services (electricity, water, sanitation, etc.)	Proper furniture	Previous room
1	9	11,9	8,0	SPACIOUS ROOM	⊙												
2	9	10,4	7,0	PROPER FURNITURE (CHAIRS, STRETCHER, ETC.)							▲	O	O			⊙	
3	9	9,0	6,0	SINK, FAUCET, PLUGS, LUMINAIRES, ETC.											⊙		
4	9	9,0	6,0	SPECIFIC SPACES (TO NUDE, ACCELERATE, ETC)	⊙								O			O	⊙
5	9	13,4	9,0	STABLE AND ADEQUATE AMBIENT TEMPERATURE	O	⊙	⊙	⊙	▲	⊙				▲	▲		
6	9	9,0	6,0	STABLE AND ADEQUATE ENVIRONMENTAL HUMIDITY	O	⊙	⊙	⊙	▲	O					O		
7	9	7,5	5,0	STABLE AND ADEQUATE ADMOSPHERIC PRESSURE	▲	O ?	⊙ ?	⊙ ?	⊙ ?	▲					▲		
8	9	10,4	7,0	ABSENCE OF RADIATION SOURCES	▲	⊙	⊙			⊙	⊙			⊙		▲	
9	9	10,4	7,0	ROOM WITHOUT REFLECTIVE ZONES						O	⊙		O	⊙		O	
10	9	9,0	6,0	POSSIBILITY TO COLLECT AND CUSTODIATE OBJECTS								⊙	⊙			O	

Fig. 5. Weights and relationship between demanded qualities and quality characteristic (‘Hows’ - ‘Whats’).

On the other hand, regarding the analysis of the important relationships between the ‘hows’ and ‘whats’, Fig. 6 shows the strength of the existing relationships between ‘hows’ themselves, that is, if there are strong relationships among the demanded characteristics. In our case, the strong relationship between the appropriate insulation of the room and a correct air conditioning was stressed, existing in turn a strong relationship between the correct insulation and the elements of the walls, such as the case of windows. On the other hand, there was also a certain strength in the relationship between background, furniture, item deposit, and equipment, which are related in most cases to the avoidance of radiation sources, reflective or light, or to the cleaning and preparation of the patient.

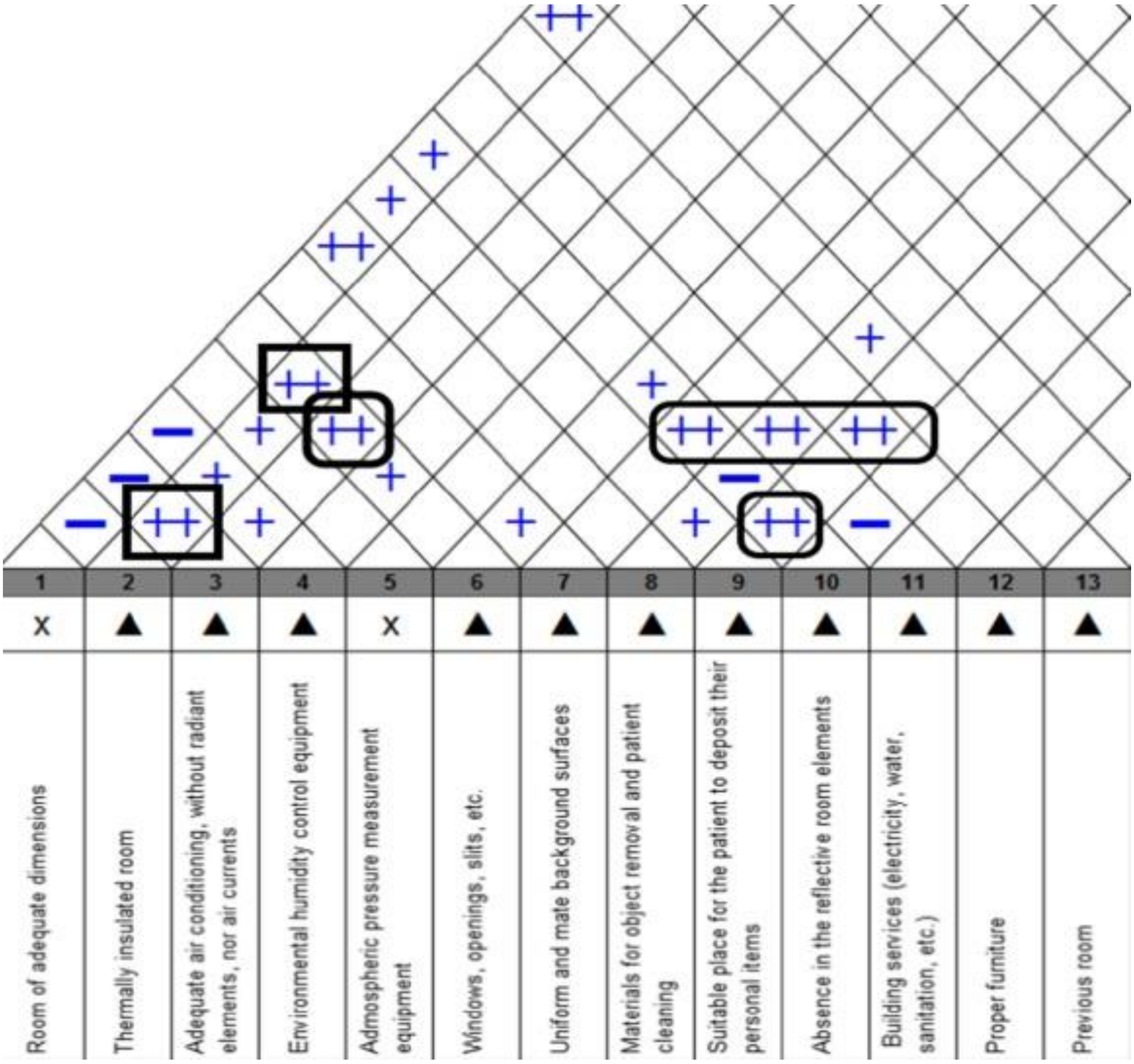

Fig. 6. Correlations between demanded characteristics.

On the other hand, Fig. 7 shows the limit values of each 'how' considered in the references and by the experts consulted, thus stressing, as previously seen, that a steady temperature between 21 and 23 °C was the most important requirement. Although the insulation of the room, its minimal dimensions, a relative humidity between 40 and 60%, or the lack of reflective elements were also highlighted, all authors indicated that if temperature and, to a lower extent, humidity are within these limits, the remaining parameters could be considered as a secondary character, unless their presence is very strong regarding their negative aspects.

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Target or Limit Value	>2X3 m	Enclosure with insulating material	21 y 23 °C	40-60%	900-1000hPa o mb	Nearly zero radiation and current emission	Behind the subject and with the largest possible area	Sufficient, disposable and that provides humidity	Opaque and that hides objects, especially	Avoid decoration and reflective equipment	Electric power outlets 16-25A, 1 evac. water, lux etc.	Table, chairs, bed, etc	Equipped to acclimate, hang clothes, etc.
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)													
Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	9	9	9	9
Weight / Importance	273,1	317,9	362,7	268,7	89,6	280,6	198,5	111,9	170,1	201,5	128,4	189,6	80,6
Relative Weight	10,2	11,9	13,6	10,1	3,4	10,5	7,4	4,2	6,4	7,5	4,8	7,1	3,0

Fig. 7. Target or limit value, maximum relationship value in column, weight/importance, and relative weight.

As the weight or importance data of the 'hows' showed in Fig. 7 are of great interest according to the objective of this research, Fig. 8 represents them in descending order to provide a better information about which ones should be more considered.

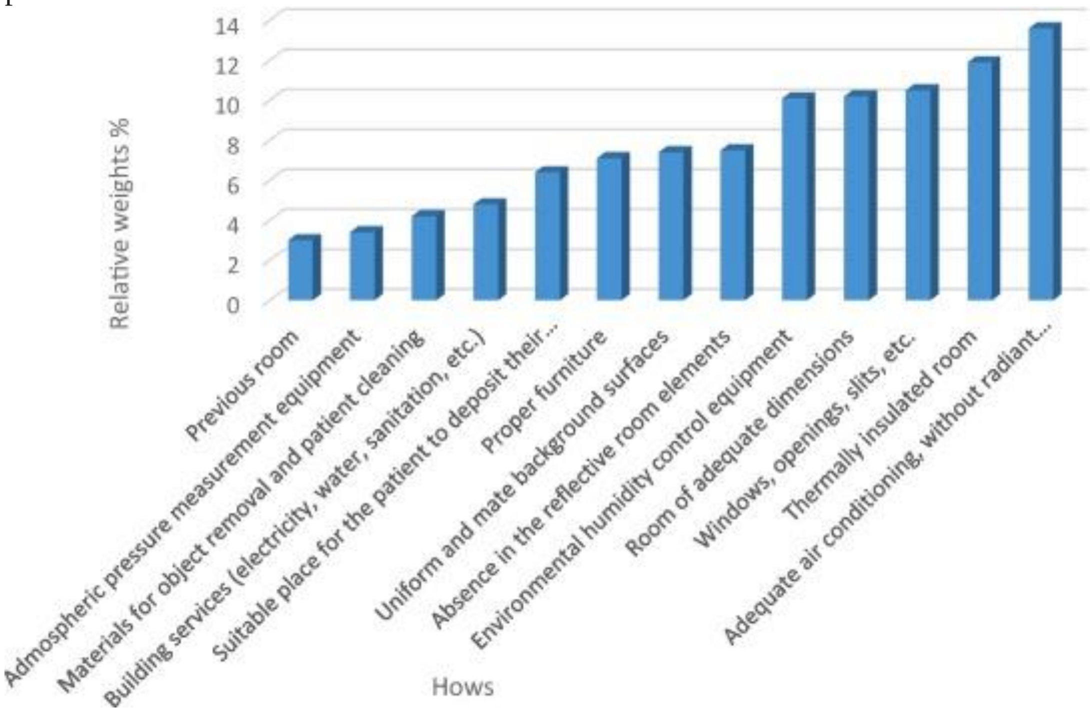

Fig. 8. 'Hows' ordered according to the weights which resulted from the application of the QFD methodology.

Regarding the specific enclosures of medical emergency units, Fig. 9 shows in detail, from 0 to 5, the marks obtained by each factor 'whats' for each of the most typical rooms of medical emergency units. This has been possible thanks to the fact of knowing the characteristics of such enclosures, since they are available in the standards and recommendations published by the Government of Spain or regional governments [27], [28], in Spanish technical standards such as the Building Technical Code (CTE) [29], and in some European standards on which Spanish standards are in turn based, such as the UNE standard for air conditioning systems in hospitals [30], among others. So, Fig. 9 shows that triage, consultation, examination, treatment and observation rooms fulfilling the Spanish standards obtained positive assessments (≥3/5) in most cases. However, there is some lack of specific spaces to prepare the patient, but it has little influence on positive evaluation in general.

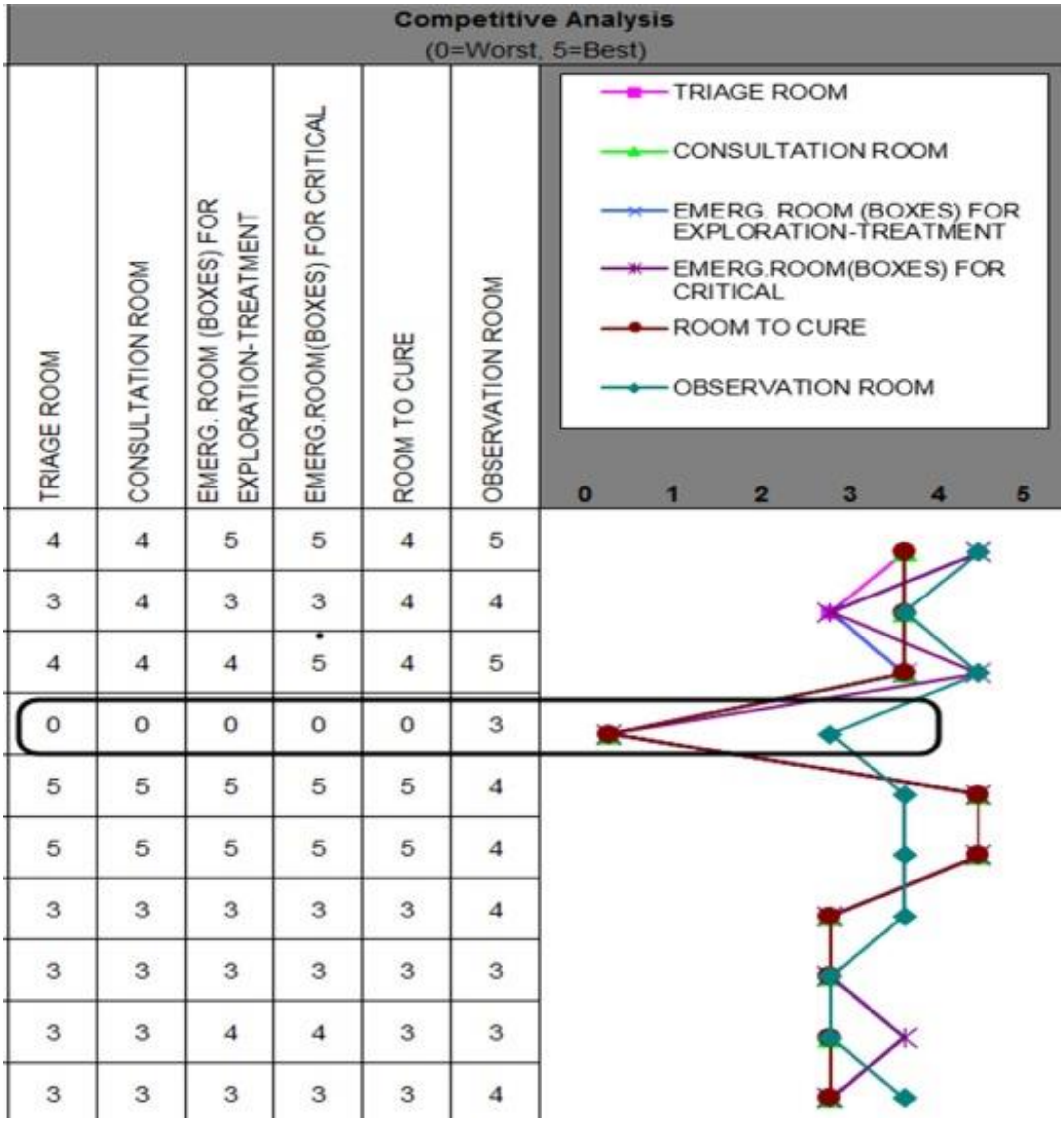

Fig. 9. From 0 to 5, the mark obtained by each factor 'whats' for each of the most typical rooms of medical emergency services in Spain.

4. Discussion

Regarding the final assessment of the research, and particularly regarding to the meaning of findings or results, the first aspect to be indicated is that they provided a quite approximate idea of which factors are the most interesting. As Fig. 7, Fig. 8 show, air conditioning was the most outstanding factor (13.6/100), although this mark (13.6 over 100) could be considered a little bit higher taking into account that the factor was closely related to other factors which in turn had a high mark, such as the thermal insulation of the room by avoiding thermal runaways or inputs (11.9/100), the dimensions of the enclosure to be acclimated (10.2/100) and humidity (10.1/100). In addition, these appreciations coincidence with most of the indications given by experts and specialised references, so the results did not differ from those expected, thus constituting a clear indication of the validity of the methodology developed. Regarding the remaining factors, although the need of not having radiant and reflective elements, among others, is stressed, these factors depend on the design or construction of enclosures as well as on the staff supplying, using and maintaining them, so the assessment result of these factors could be considered as a fixed picture in a certain moment regarding the architectural design-construction, unlike those aspects depending on the human factor regarding the supply, use and maintenance of each enclosure.

On the other hand, regarding the medical emergency enclosures analysed, whose characteristics fulfilled the standards of the Spanish regulation, it was evident that infrared thermography cameras could be used as an useful or supportive tool for the medical diagnosis in the most usual enclosures for this type of medical services, that is, triage, consultation, examination, treatment, and observation rooms. Nevertheless, and based on the consultations made, these enclosures, although initially fulfilled such standards, could present certain characteristics which could distort the results of the thermography images mentioned above because, as in these services there are sometimes moments with too people, it is possible that certain factors related to the appropriate supply, use and maintenance of each enclosure could include elements which modify the suitability of such enclosures. Therefore, doors permanently opened, visible medical material, a high number of people in certain moments, the lack of a periodic control of air conditioning, the lack of monitoring an appropriate action protocol, etc. could lead to the fact that a positive initial assessment of an enclosure to use infrared cameras turns into a negative assessment later.

5. Conclusions

The results show that the methodology used is an appropriate and new option to assess various indoor spaces to use infrared thermography cameras and even to conduct comparative studies. In addition, the great importance of certain factors, such as the environmental conditioning (temperature-thermal insulation, humidity, and air currents, among others), is proven. In this regard, if the camera meets certain specific characteristics, then the elements or factors which could imply distortions in the results of the images and measurements obtained could be found by applying this methodology, thus decreasing the probability of errors which, in the case of medical emergencies, could be crucial as they are usually related to the following diagnostic potential. On the other hand, the application of this methodology also constitutes an option to conduct comparative studies among various enclosures and even among similar enclosures, but in various buildings or, as in our case, in various medical emergency units or services. Regarding the enclosures belonging to the medical emergency units studied, if these enclosures meet the Spanish standards and recommendations related to their architectural and equipment characteristics, then it is verified that the suitability level of these spaces is appropriate, at least in the basic aspects of the triage, consultations, examination, treatment, and observation rooms. Finally, regarding the limitations of the methodology, an assessment of the suitability of enclosures cannot be considered as a fixed picture as there are factors which could vary throughout time, particularly when the enclosures are medical emergency services where the fluctuation related to their use could be important. Therefore, it would be advisable to make periodic assessments by using the proposed methodology, and those assessments should be periodic depending on whether they are diagnoses which require to be more based on quantitative or qualitative elements respectively. On the other hand, it would be advisable to experiment with this methodology and even to implement it systematically in the various spaces where these cameras are usually used, since more data could be provided to consolidate their benefits and a continuous updating of the methodology model presented could be presented, as well.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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