Examining the Condition of Hospital Lifts after an Earthquake

Emre Pınarbaşı[1], Tolga Balcı[1], Adem Candaş[2], Eren Kalay[2], C. Erdem İmrak[2]

[1]Emlak Konut Asansör Sistemleri San. ve Tic. A.Ş., Istanbul, Turkey
[2]ITU Elevator Technologies Laboratory, Istanbul, Turkey

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Abstract. Among public buildings ordinarily used by the public, health facilities hold a critical priority and importance. During field visits following two major destructive earthquakes in Turkey in the last 15 years, damage to hospital lifts in particular has drawn attention. Hospital lifts, which are of great importance in the treatment of earthquake victims, are desired to be earthquake-resistant after an earthquake. In this study, the damages detected in hospital lifts following the 2011 Van earthquake and the 2023 Kahramanmaraş twin earthquakes in Turkey are evaluated, and the techniques developed and implemented for earthquake-resistant lifts are explained with examples.

1 INTRODUCTION

Hospitals have an important role among public buildings after destructive earthquakes. They are expected to continue healthcare services and to respond to emergency medical demand during the post-earthquake period. Therefore, the seismic performance of hospitals should not be evaluated only by considering the structural safety of the building. Non-structural components and service systems can also affect the functionality of a hospital. Damage to these systems may cause interruption of hospital services even when the main structural system remains usable [1,2]. Hospital lifts are one of the important service systems for maintaining vertical transportation in healthcare buildings. They are used for the transportation of patients, stretchers, beds, medical staff, visitors, medical devices, medicine, food, and service equipment. In ordinary buildings, lift failures generally cause accessibility and comfort problems. However, in hospitals, lift failures can directly affect patient transfer, emergency response, and internal logistics. For this reason, the post-earthquake condition of hospital lifts is an important issue for hospital functionality and disaster preparedness.

A considerable amount of literature has been published on hospital resilience and post-earthquake functional recovery. These studies have shown that hospital functionality depends on structural damage, non-structural damage, utility systems, organisational capacity, and recovery time [3–5]. Several studies have also focused on non-structural components in past earthquakes and reported that damage to these components may lead to loss of use and long repair periods [6,7]. However, hospital lifts are generally considered as a part of general building services, and detailed field observations on their post-earthquake damage are still limited. Lift systems contain many mechanical and structural components that may be affected by seismic motion. Counterweight frames, guide rails, rail brackets, guide shoes, suspension ropes, sheaves, landing doors, car frames, shaft walls, and seismic detection systems can influence the safe operation of lifts after earthquakes. Typical earthquake-related problems include counterweight derailment, guide rail or bracket deformation, rope displacement, landing door malfunction, car damage, and debris falling inside the shaft. These problems can be more critical in hospitals because patients and medical equipment may need to be transported immediately after an earthquake.

Earlier works on lift components, seismic effects, and emergency operation of lift installations provide a background for the present study. Guide rail brackets and fasteners were examined under earthquake loading, and different bracket designs were compared in terms of their structural response [8–10]. The behaviour of lift installations under emergency conditions and the damages observed in hospital lifts located in earthquake regions were also discussed in recent studies [11]. In addition, wire ropes and safety gear brake blocks were investigated using experimental, numerical, and image-

processing-based methods [12,13]. Therefore, the present study extends these previous efforts by focusing specifically on field observations from hospital lifts after major earthquakes.

Turkey is located in a seismically active region, and many hospital buildings are located in earthquake-prone areas. The 2011 Van earthquake and the 2023 Kahramanmaraş earthquakes provided important field observations related to hospital lifts (Figure 1). These two earthquakes also occurred in different regulatory periods.

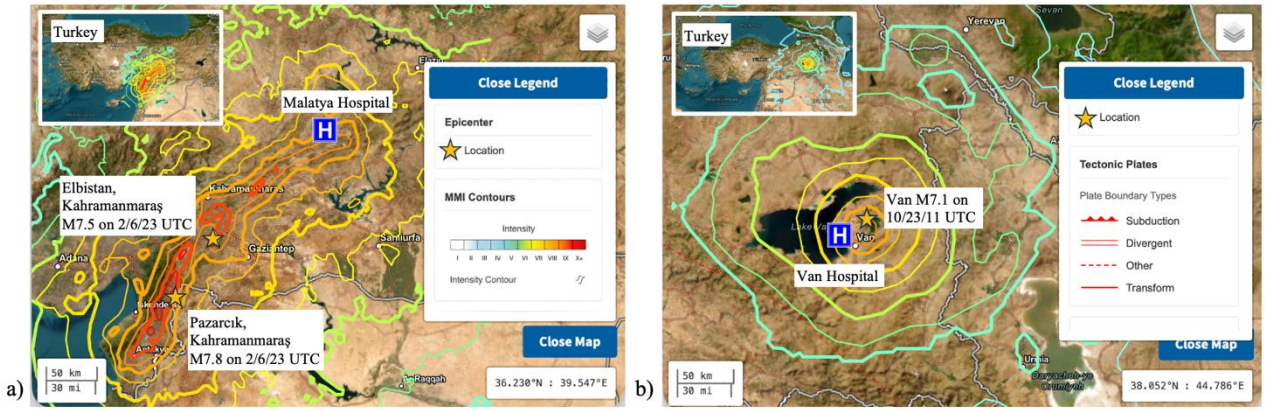


Figure 1 Location and epicentre map of the a) 2 June 2023 Kahramanmaraş Earthquakes [14] and b) 23 October 2011 Van earthquake [15] (adapted from U.S. Geological Survey)

The 2011 Van earthquake occurred before the implementation of EN 81-77 [16], provisions for lifts subject to seismic conditions in Turkey. The 2023 Kahramanmaraş earthquakes occurred after these provisions had become part of national lift regulations. Although these two cases do not provide a fully controlled comparison, they allow the evaluation of observed damage types under different regulatory conditions. This study presents field observations from hospital lifts inspected after the 2011 Van and 2023 Kahramanmaraş earthquakes. The observed damages are evaluated to identify common failure mechanisms and to discuss the remaining weak points of hospital lift systems. The seismic vulnerability of hospital lifts is first summarised. Then, field observations from the Van and Kahramanmaraş earthquakes are presented. Finally, the observed damage patterns are compared and practical design and operational implications are discussed.

2 HOSPITAL LIFTS AND FIELD OBSERVATIONS

Hospital lifts are exposed to different functional and mechanical demands compared with ordinary passenger lifts. They are used for patient beds, stretchers, wheelchairs, medical devices, staff circulation, visitors, service equipment, and daily hospital logistics. During and after an earthquake, these functions become more critical because the hospital must continue emergency response and patient transfer. Therefore, the seismic design of hospital lifts should consider both passenger safety and the continuity of vertical transportation.

According to EN 81-77, lifts subject to seismic conditions are classified by considering the design acceleration, which depends on seismicity, soil conditions, and the importance class of the building. Hospitals are included in the highest importance class because their integrity is vital for civil protection during earthquakes. The required precautions increase from Category 0 to Category 3. While Category 0 does not require additional seismic provisions, Category 1 includes measures such as prevention of snag points, counterweight retaining devices, rope retaining devices, compensation chain protection, guide rail systems, machinery, electrical installations in the shaft, and user information. Category 2 adds measures related to car and counterweight guide systems, car door

locking devices, and special car behaviour in the case of power failure. Category 3 additionally requires a seismic detection system and seismic operation mode.

The most critical components for seismic safety are the counterweight system, guide rails, rail brackets, suspension ropes, sheaves, landing doors, car frame, and shaft equipment. Counterweight derailment, bracket deformation, rope displacement, and landing door malfunction may prevent safe operation after an earthquake. Therefore, mechanical retaining measures and active seismic detection systems should be considered together, especially for hospital lifts that are expected to support post-earthquake service continuity.

2.1 Field Observations after the 2011 Van Earthquake

The 2011 Van earthquake occurred on 23 October 2011 in eastern Turkey with a moment magnitude of Mw 7.1. Since the event occurred before the implementation of EN 81-77 provisions in Turkey, the inspected lifts were not designed according to the current seismic lift requirements. Therefore, the observations from this earthquake provide useful information about the behaviour of hospital lifts in the pre-standard period. Representative examples of these damage types are shown in Figure 2.

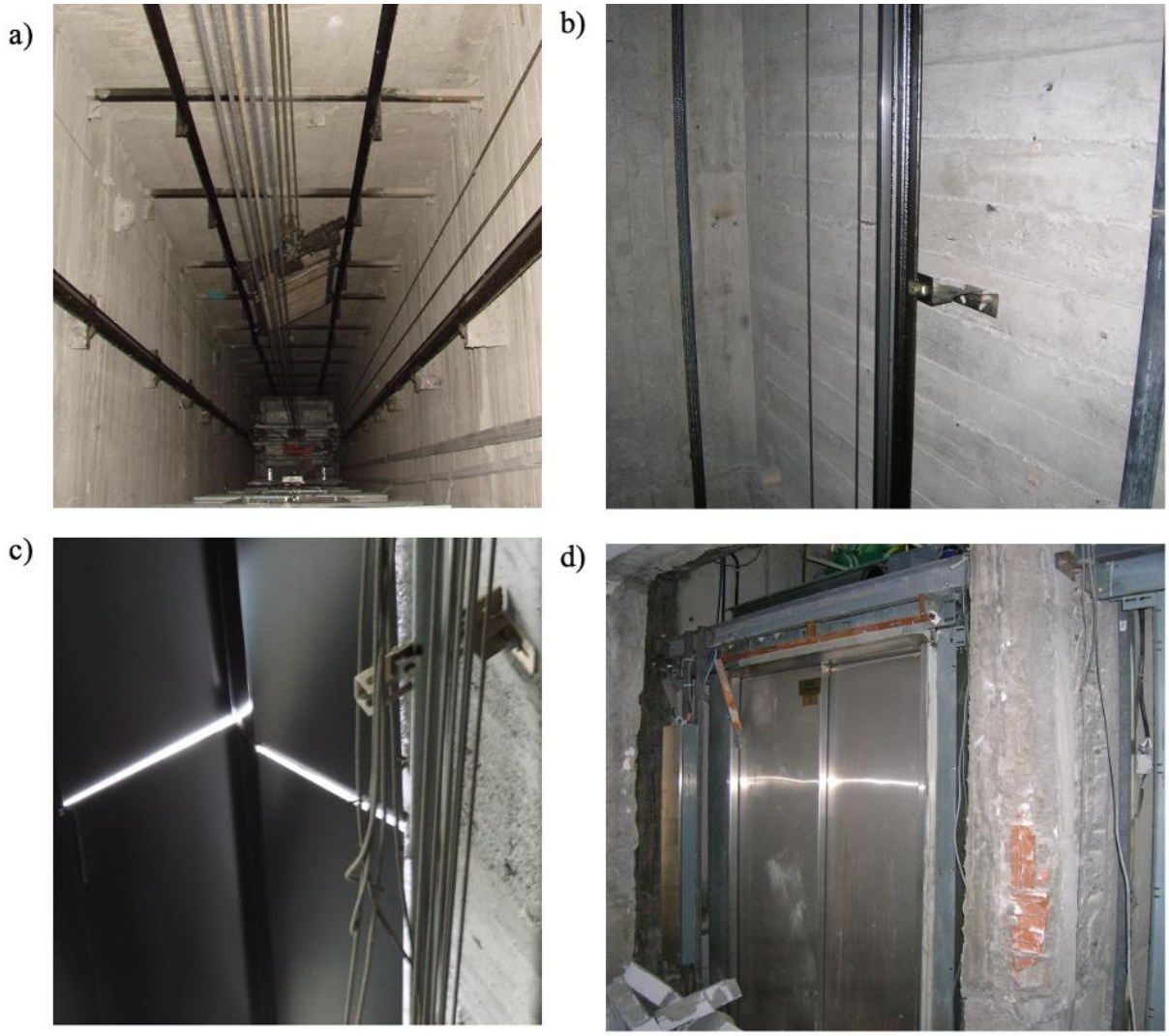


Figure 2 Damage observed in hospital lifts after the 2011 Van earthquake: (a) counterweight derailment, (b) guide rail/bracket damage, (c) rope displacement, and (d) landing door damage

After the earthquake, 25 lifts were inspected in two hospitals, including Van Speciality Hospital and Medical Park Hospital. The inspected lifts had different configurations, including hydraulic, machine-room, and machine-room-less systems. A common feature was the use of rigid guide shoes and concrete counterweights. At Van Speciality Hospital, the hydraulic lift did not show visible mechanical damage, while two machine-room lifts were not operational mainly due to landing door problems. More severe damage was observed at Medical Park Hospital. Counterweight derailment, guide rail/bracket damage, landing door damage, shaft wall debris falling onto the car roof, and suspension ropes leaving the sheaves were detected in several lifts. The 2011 Van observations show that lift failure may occur even when the main building structure remains usable. These findings are used as the pre-standard reference case in the comparative assessment of this study. In addition to the observed damage to the elevator components, structural damage was also observed in the hospital building, particularly in the elevator shaft walls, with debris falling onto the car roof.

2.2 Observations after the 2023 Kahramanmaraş Earthquake

On 6 February 2023, two major earthquakes occurred in the Pazarcık and Elbistan districts of Kahramanmaraş and affected a large region in southern and eastern Turkey. Many hospitals in the region had to continue their service under difficult post-earthquake conditions. Representative examples of the observed bracket damage and seismic sensor arrangement are shown in Figure 3.

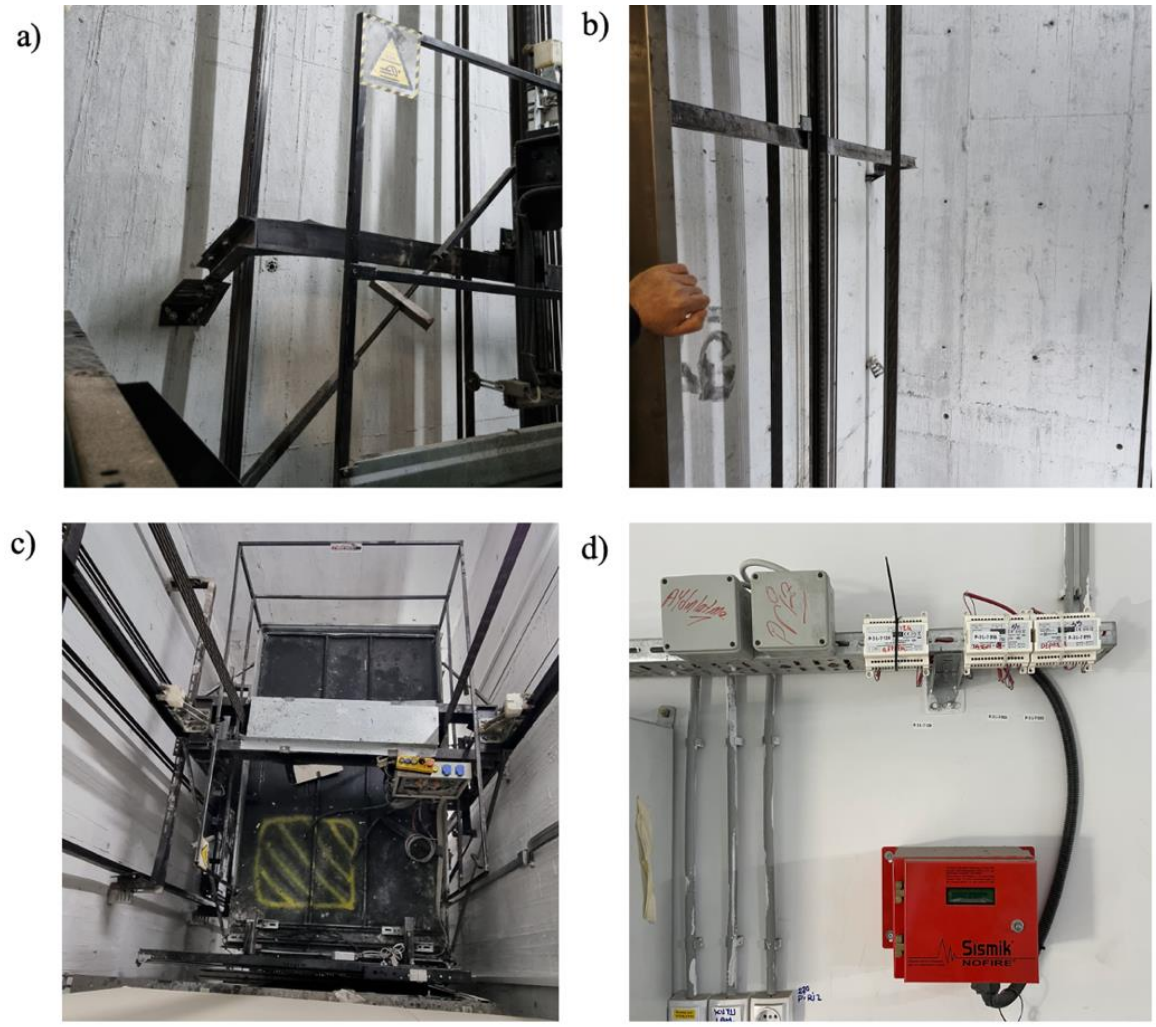


Figure 3 Damage and seismic safety observations in hospital lifts after the 2023 Kahramanmaraş earthquakes: (a) guide rail bracket deformation, (b) damaged bracket region, (c) car, and (d) seismic sensor installed in the lift system

The observations related to hospital lifts are mainly based on field examinations carried out in Malatya. In Malatya, 16 lifts were inspected after the earthquakes. The inspected lifts included machine-room, machine-room-less, and hydraulic systems. In machine-room and machine-room-less lifts, counterweight derailment, counterweight shoe damage, guide rail bracket damage, counterweight slab damage, and guide rail bending were observed. No visible damage was recorded in the inspected hydraulic lifts. These observations indicate that the counterweight assembly and guide rail support system remained the most critical components in the 2023 damage sample.

Additional observations were made at Malatya Turgut Özal University Training and Research Hospital, which included 51 lift units in different blocks. Among these units, eight machine-room lifts with a capacity of 2500 kg and two machine-room-less lifts with a capacity of 1600 kg were equipped with seismic sensors. These sensors were activated during the earthquakes. Some guide rail brackets in the machine-room lifts were deformed or damaged, while rope derailment from sheaves was not observed.

The 2023 observations show a different damage pattern compared with the 2011 Van earthquake. Rope displacement from sheaves and widespread landing door faults were not dominant failure modes, and seismic sensors were activated in several lifts. However, bracket deformation and counterweight-related damage show that some critical weak points continued in the post-standard period. The observed damage was limited to the elevator components within the hospital building. No signs of structural damage to the hoistways, machine rooms, or landing areas were observed.

3 COMPARATIVE ASSESSMENT

The field observations from the 2011 Van and 2023 Kahramanmaraş earthquakes show both similar and different damage patterns. These two cases should not be considered as a fully controlled comparison because the inspected hospitals, lift types, installation years, maintenance conditions, local ground motions, and building responses were different. However, the observations provide useful information about the weak points of hospital lifts under seismic effects. The 2011 Van earthquake represents a pre-standard case for EN 81-77 provisions in Turkey, while the 2023 Kahramanmaraş earthquakes represent a post-standard case. A comparative summary of the observed damage patterns is presented in Table 1.

Counterweight-related problems were the most repeated failure mode in both earthquake cases. In Van, counterweight frame derailment was observed in several inspected lifts. In the 2023 Malatya sample, counterweight derailment, shoe damage, and counterweight slab damage were also recorded. Guide rail and bracket damage was another common problem. These observations show that the counterweight system and guide rail support system should be considered together in seismic lift design. Some damage types were more dominant in the 2011 Van observations. Landing door faults, rope displacement from sheaves, and shaft wall debris falling onto the car roof caused operational problems in several lifts. In the 2023 Malatya sample, these damage types were not dominant, and rope derailment from sheaves was not observed in the inspected hospital lifts. The activation of seismic sensors in Malatya also indicates that active seismic safety systems can contribute to safer lift behaviour. However, the observed bracket damage and counterweight-related problems show that mechanical design measures and active detection systems should be considered together.

The comparison shows that some failure modes, such as rope displacement and widespread landing door faults, were less prominent in the 2023 observations. On the other hand, counterweight-related instabilities and guide rail support damage continued to be important weak points. Therefore, the results suggest a partial improvement in post-earthquake lift behaviour after the adoption of seismic provisions, but they also show that further attention is required for counterweight stability, guide rail brackets, anchorage details, and post-earthquake inspection procedures.

Table 1 Comparative summary of observed damage patterns after the 2011 Van and 2023 Kahramanmaraş earthquakes

Observed issue	2011 Van	2023 Malatya	Interpretation
Counterweight frame derailment	Frequently observed in several inspected lifts	Observed in MR and MRL lifts	Persistent weak point
Counterweight shoe or slab damage	Observed in damaged counterweight systems	Observed in inspected MR/MRL lifts	Requires better restraint of counterweight blocks
Guide rail / bracket deformation	Observed together with counterweight problems	Observed in some MR lifts	Bracket and anchorage design remains critical
Landing door faults or damage	Common and caused loss of operation in some lifts	Not dominant in the Malatya sample	Possible improvement, but sample-dependent
Rope derailment from sheaves	Observed in MRL lifts	Not observed in inspected sensor-equipped lifts	Rope retaining measures may reduce this risk
Shaft wall debris on car roof	Observed in MRL lifts	Not dominant in the Malatya sample	Shaft integrity and debris protection remain important
Hydraulic lift damage	No visible damage in inspected example	No visible damage in inspected hydraulic lifts	Should be interpreted cautiously due to limited sample
Seismic sensors	Not applicable in inspected pre-standard lifts	Present and activated in several lifts	Positive contribution to emergency operation

4 DESIGN AND OPERATIONAL IMPLICATIONS

The field observations show that hospital lift safety during earthquakes cannot be improved only by adding a seismic sensor. Mechanical components, shaft arrangement, control logic, and post-earthquake inspection procedures should be considered together. In particular, counterweight stability, guide rail support systems, rope retaining measures, and emergency operation functions remain the main issues for hospital lifts in seismic regions. The counterweight system should be one of the first components checked in seismic lift design. In both earthquake cases, counterweight-related problems were observed. Therefore, counterweight frames should be designed to prevent displacement of counterweight blocks during seismic motion. Concrete blocks should be mechanically restrained inside the frame, and the frame should be sufficiently rigid to prevent the blocks from jumping out or damaging the car and shaft components.

Examples of retaining devices for the car and counterweight systems are shown in Figure 4. These precautions are especially important for hospital lifts because even local damage in the counterweight system may cause long service interruption. Guide rail brackets, rail connections, and anchorage details should be designed considering the seismic design acceleration. The car, counterweight, guide rails, brackets, and fixing elements should be evaluated together. Ropes, sheaves, governor ropes,

compensation chains, and travelling cables should also be protected against displacement and snagging. These measures can reduce the risk of rope derailment, shaft damage, and secondary failures after seismic motion.

Emergency operation and post-earthquake inspection procedures should also be defined specifically for hospital lifts. In seismic lift categories where special operation is required, the lift should be able to move the car to the next possible landing in case of normal power failure. For Category 3 lifts, seismic detection systems should activate the seismic operation mode, cancel registered calls, prevent new calls, and move the lift at reduced speed to a suitable landing when possible. Before returning the lift to normal service, the counterweight frame, guide rails, brackets, anchors, ropes, sheaves, landing doors, car frame, shaft walls, and seismic sensor system should be checked. Priority should be given to stretcher and patient-bed lifts because they are directly related to emergency healthcare operations.

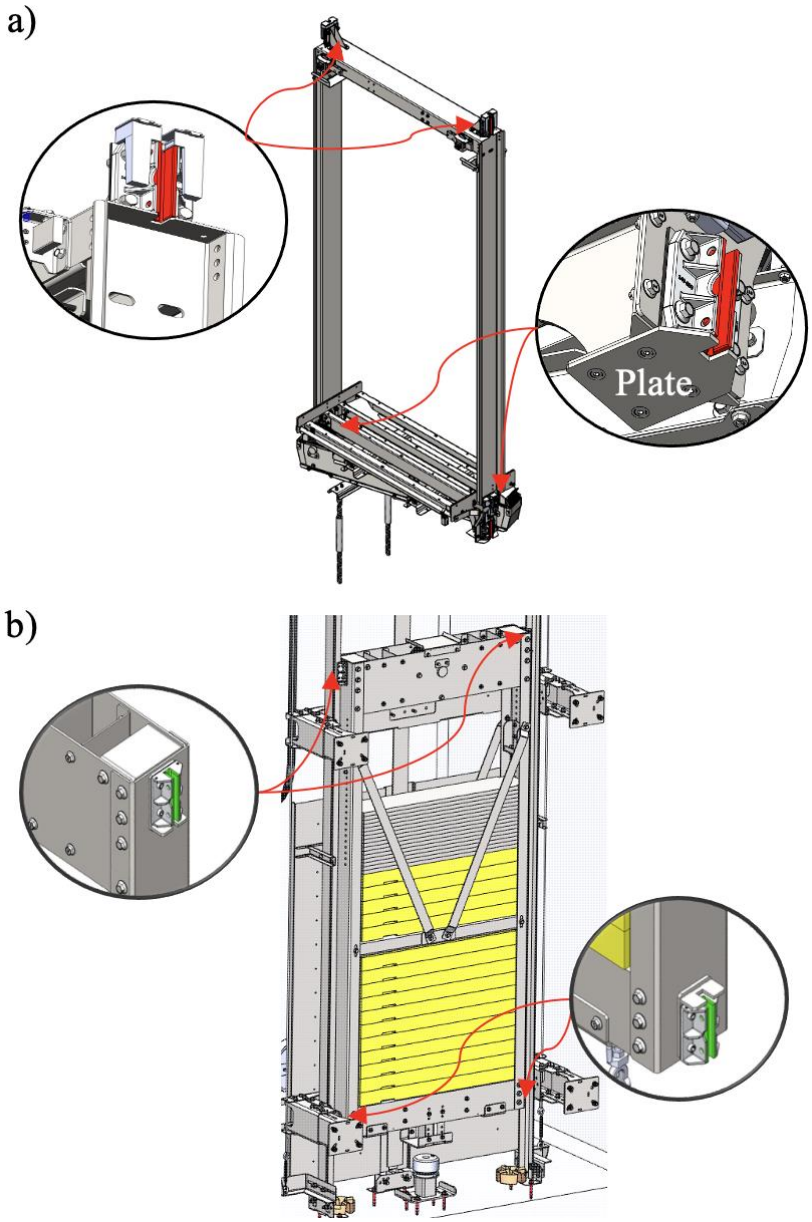


Figure 4 Examples of seismic retaining devices: (a) car retaining device and (b) counterweight retaining device

Overall, the design and operation of hospital lifts in seismic regions should be based on a combined approach. Passive mechanical precautions such as counterweight retaining, bracket strengthening, and rope protection should be used together with active systems such as seismic sensors and emergency return operation. This combined approach can reduce passenger entrapment, limit mechanical damage, and support the post-earthquake functionality of hospitals.

5 CONCLUSION

This study evaluated field observations from hospital lifts inspected after the 2011 Van and 2023 Kahramanmaraş earthquakes. The observations showed that hospital lifts are critical non-structural systems for post-earthquake functionality because their failure can affect patient transfer, emergency response, and internal hospital logistics. Counterweight-related problems and guide rail support damage were identified as the most persistent weak points in both earthquake cases. In the 2011 Van observations, counterweight derailment, landing door faults, rope displacement, shaft debris, and bracket deformation were observed, while in the 2023 Malatya observations, rope displacement and widespread landing door faults were not dominant and seismic sensors were activated in several lifts. These findings suggest a partial improvement in post-earthquake lift behaviour after the implementation of seismic provisions; however, the observations do not provide a fully controlled statistical comparison. Further attention is required for counterweight retaining systems, guide rail brackets, anchorage details, rope protection, seismic detection systems, and post-earthquake inspection procedures. For hospitals located in seismic regions, passive mechanical precautions and active emergency operation systems should be considered together to reduce passenger entrapment, limit mechanical damage, and support the continuity of hospital services after major earthquakes.

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BIOGRAPHICAL DETAILS



Emre PINARBAŞI is a R&D Unit Manager at Emlak Konut Asansör (EKA). He completed his B.Sc. in Mechanical Engineering at Karabük University in 2013. Throughout his career, he has contributed to the development of both machine-room and machine-room-less lift systems. His expertise lies in enhancing the design, functionality, engineering calculations, and efficiency of lift systems. He also has expertise in project management.



Tolga BALCI is a Senior R&D Engineer at Emlak Konut Asansör (EKA). He completed his B.Sc. in Automotive Engineering at Gazi University in 2019. Throughout his career, he has contributed to the development of both machine-room and machine-room-less lift systems, as well as hydraulic lift technologies. His expertise lies in enhancing lift systems' design, functionality, and efficiency.



Dr. Eren KALAY is a research assistant at Istanbul Technical University (ITU), specializing in mechanical engineering. He received his B.Sc., M.Sc., and Ph.D. degrees in Mechanical Engineering from ITU in 2014, 2017, and 2023, respectively. His research interests include computer-aided engineering, the Discrete Element Method, materials handling, and artificial neural networks.



Dr. Adem CANDAŞ is an Assistant Professor at Istanbul Technical University (ITU). He received his B.Sc., M.Sc., and Ph.D. degrees in Mechanical Engineering from ITU in 2010, 2013, and 2021, respectively. His research interests include fracture mechanics, computer-aided engineering, numerical analysis, materials handling systems, and lift systems.



C. Erdem İMRAK is a full-time Professor at Istanbul Technical University (ITU). Professor Imrak received B.Sc., M.Sc., and Ph.D. degrees in Mechanical Engineering from ITU in 1990, 1992, and 1996 respectively. He has carried out research into computer-aided engineering, CAD/CAM, numerical analysis, materials handling, and especially lift systems. Currently, his activities include an Honorary Member of ASYAD; a Member of the Safety, Education & Training Committee of ELA; a Member of the ASME; a Member of the OIPEEC; a Member of the IAEE; a Member of the Chamber of Mechanical Engineers in Turkey.