ISSN 2347 - 3983
Volume 8. No. 4, April 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter30842020.pdf
https://doi.org/10.30534/ijeter/2020/30842020

Elevator Group Control System EGCS with Risk Management

Malan D. Sale[1], Dr. V. Chandra Prakash[2]
[1]Research Scholar, Department of Computer Science & Engineering, K.L.E.F., Vaddeswaram, Andhra Pradesh, India,mdsale2006@gmail.com
[2]Professor, Department of Computer Science & Engineering, K.L.E.F., Vaddeswaram, Andhra Pradesh, India,vchandrap@gmail.com

ABSTRACT

A crucial area in today's situation is to provide efficient vertical transportation to an increasing population. There is a necessity to install multiple lifts in the building instead of a single elevator to satisfy all passenger requests. People face many transportation problems when one of the elevators shut down its working. To minimize the passenger's inconvenience, there is a necessity of an efficient mechanism to reschedule the elevators according to the installed algorithm. The proposed study focuses on elevator scheduling in the Elevator Group Control System (EGCS) with proactive and reactive risk management techniques. The proposed EGCS handles the situations that may occur due to the elevator shut down and hiring elevators. Once the system detects elevator failure or elevators are booked for a particular period, the signal sends automatically or manually by the administrator. After receiving the message, the EGCS reconfigures installed elevator scheduling algorithms and dynamically reschedule the elevators.

Key words: EGCS, rescheduling, emergency evacuation, even-odd system, risk management.

1. INTRODUCTION

Providing efficient transportation to an increasing population is a crucial area in today's situation. The transportation problem needs to be addressed by providing a solution either in a horizontal direction or in a vertical direction. The horizontal transportation problem is resolved by transportation mediums like buses, trains, cars, etc. The vertical transportation problem occurs in buildings when people want to move from one level to another. People use the staircase to travel between floors. The problem arises when the building height increases. The use of stairs to move to the higher levels is not possible for all people.

Along with stairs, elevators can be used as vertical transportation medium in tall buildings. The building floors may contain schools, offices, shopping malls, and residential apartments. Using a single elevator to provide vertical transportation is not the right choice. To satisfy all passenger requests, there is a need to install numerous elevators in the building. With multiple elevators, the problem of elevator coordination and dispatching occurs. This problem is solved by introducing the EGCS. Based on the type, height, and population in building, the mandatory quantity of elevators can be installed in EGCS. According to the nature of the building, the builder may opt for different elevator configurations. In the traditional elevator (lift) system, all lifts stop at each floor, resulting in more stops and maximum waiting time. Reducing the amount of lifts/elevator stops minimizes the passengers waiting time and improves system performance.

The proposed studies focus on different scheduling algorithms in EGCS like even-odd scheduling, traffic, and time-based floor priority and scheduling during emergencies. The proposed research focuses on EGCS with one or all of the above scheduling types. Based on the applied scheduling algorithm, the EGCS handles incoming hall call and car call requests.

The even-odd scheduling approach divides the building floors into two sections, even floors, and odd floors. The even-numbered elevators are allotted to satisfy even floor calls, and odd-numbered lifts are assigned to fulfill odd floor requests [26]. The proposed study [27] focuses on commercial buildings with schools, shopping malls, and offices located on different floors. More traffic levels/floors are identified based on the respective floor requests. Traffic based floor priority is assigned to the upper traffic floors. Maximum elevators are allotted to high traffic floors, and fewer bins are allocated to fewer traffic floors. The study [28] focuses on EGCS with time-based floor priority elevator scheduling. The study emphasizes the usage of elevators to serve requests of high priority floors at a specific period. Based on school or office opening and closing time, elevator scheduling is proposed to minimize the excess waiting time of passengers. During morning time, the elevators are allocated to serve the calls between ground floor to school or office floor only.

Similarly, during the evening, the elevator allocation is between school/office floors to the ground level/floor only. There are no intermediary calls except one elevator during

these peak periods. Once the peak period is over, the elevator scheduling is regular.
Emergency scheduling is used once an emergency like fire, flood, or bomb detected in buildings [29]. The dynamic allocation of elevators does the population evacuation. The study proposes the usage of lifts along with stairs during emergencies. Once the EGCS detects emergency in the building, the elevators stop the normal execution and reach to the affected floor for population evacuation. After the crisis is under control, the lifts operate normally.

Due to any reason, the elevators may stop working. People face many problems if one of the lifts shut down its working and become fails. The overall elevator scheduling gets collapsed. There is a need of a mechanism that will take care of such situations. If any of the elevators not available in service, then EGCS needs to reschedule the lifts according to the installed algorithm so they can minimize the inconvenience.

The proposed scheme focuses on the elevator scheduling in EGCS to handle the situations that occurred due to the elevator shut down. Once the failure detected, the signal needs to send automatically or manually by the administrator. Once the EGCS detects one or more lifts failed and stopped working, then it reconfigures installed elevator scheduling algorithm and dynamically reschedule the elevators.
The proposed system focuses on elevator scheduling when one of the elevators is allotted for a particular floor during the marriage function or any program.

2. LITERATURE SURVEY

The proposed study [1] detects the elevator fault, sends information on the cloud and gives intimation to the maintenance department to repair the elevator. Elevator scheduling during the failure of the lift is not discussed. The study [2] focuses on the usage of Hadoop and big data approaches like apriori and k-means algorithms to analyze the elevator data from the remote location database. The study examines and predicts the probability of elevator failure, so the maintenance team can focus on these elevator faults to minimize elevator accidents. The research [3] focus on aircraft fault control system where if the actuator or elevator fails the backup actuator or lift is replaced. The study [4] focuses on the monitoring system using IoT.

The various sensors located in elevators detects the faults that occurred (if any) in the bins and sends information (the type of failure, elevator ID) to the system. The communication module sends a notification along with the address of building to technicians and Elevator Company mobile phones — the study focus on fault detection. The scheduling during elevator failure is not discussed. The elevator system is monitored by using IoT, camera, and audio system [5]. The failure of the elevator is monitored. By mounting various sensors in the elevator, the information about the elevator status, whether it is operating or failed if failed, then information about trapped passengers are sent to the residential monitoring system. The system then intimates about the failure of the maintenance team [6]. The study [7] focuses on packet rerouting procedure for a 3D network on chips, which are connected partially vertically. The study does not consider a building example to resolve the elevator-scheduling problem. The router has shared index tables of all elevators. If one of the bins fails, then the router reroutes the packets of the faulty elevator to the neighboring elevator. This type of rerouting leads to deadlock conditions as the lifts are arranged in 3D on NOC's. The study proposes other solutions to an increasing amount of elevators, which is not practical in high buildings as it may increase the hardware cost and complexity in the construction design.

The study [8] proposes a dynamic elevator allocation algorithm where the faulty elevator can reroute the incoming packets to nearby elevators. The research focuses on packet rerouting algorithms for a 3D network on chips, which are connected partially vertically. The study does not consider a building example to resolve the failure-scheduling problem. The elevator operations are divided as critical and non-critical operations in the study [9]. By using sensors, the software identifies whether one of the components in the group fails. If any element fails, then the operation is controlled by other components of the group. The study [10] introduces a fault-tolerant system to handle the inverter fault. If one of the three inverters fail, then remaining inverters provide the necessary power supply. In the study[11] software toll is designed in c# to insert the faults in the system and to detect whether the software can identify the injected faults. The presented study [12] analyzes the historical and survey data to determine the elevator failure so the maintenance team can use this information and recover the failure avoiding the risks. The study [13] focuses on the fault analysis method in the elevator door system.

The research [14] Focus on developing a pulley maintenance schedule to avoid the failures in the elevator system. The study [15] concentrates on an induction motor error analysis in an elevator (lift) system.

The approach [16] uses sensors and wireless antennas to transmit elevator status continuously to PC and mobile applications. Once the elevator failure occurs, then the responsible person can notice the sent data and take the necessary measure to overcome that failure. The study [17] focuses on an elevator monitoring system. If the timer in the controller fails, then the controller will not operate accurately. The controller responds to the hall calls by resetting the list after every three minutes interval. Once the times or controller fails, the private elevators are removed from the group control system, and elevators respond to the hall calls individually.

The study [18] focus on a safe monitoring elevator system, where if some of the microcomputers fail, then the elevator controlling by abnormal microcomputer continues its service by other microcomputers. If the elevator car controller fails, then the elevator group is connected to other elevator controllers [19]. The study [20] focuses on a system with at least two system processors operating cooperatively. If one of the processors is not working properly, then the system reinitializes. After initialization, if the system does not work properly, then the system automatically allows the individual lifts to function independently. If one of the floor controllers fails, then another remote controller [21] directs elevators. Elevator control programs control the elevators [22]. If the first elevator control program fails, then the function is bypassed to other elevator control programs, and the elevator continues its working by another program when one of the elevator risers fails the elevator, control transfers to other risers, and continues its operation [23].
Previous studies propose the solution to handle emergencies in the building but not focuses on the answers to schedule elevators when one of the elevator failures detected by the system.

RFID sensors are used to collect floor population data. The studies focus on zoning based algorithm to handle emergency conditions [24] [25]. The studies do not focus on elevator fault emergency scheduling.

3. PROPOSED SYSTEM

The proposed method focuses on emergency scheduling when elevator failure occurs. Once the EGCS detects elevator failure, all elevators stop working immediately, completes the current operation, and arrive at the ground level/floor to serve the calls with the new rescheduled algorithm.

Consider a 20-floor commercial building with offices, hospitals, and schools located on different floors. Assume a school arranged a conference on a 10th floor on a particular date. The registered participants want to reach the 10th floor on the conference date. As per the installed elevator configurations, the lifts may stop either at each level, even/odd floor, or at a particular story. The participants may face inconvenience and long waiting times for the elevator. The conference manager may book a single lift or multiple lifts for conference floors for a specific period in advance.

Consider a case if an emergency occurs in the hospital due to the unavailability of an elevator or fewer elevators, the situation may become worse. The suggested method resolves this problem by presenting a new approach to proactive risk management to handle such type of risk that may occur in the hospital or at any level of the building. The proposed scheduling method offers the facility of hiring an elevator for a particular period and rescheduling of available elevators to minimize the people's inconvenience and to reduce the risk. As in advance, the information of unavailable elevators is available with administrator he/she can send a signal to EGCS about this and allots the required lift cars to demanded floors. Accordingly, the EGCS detects the working elevators and reschedules the elevators as per the installed configurations.

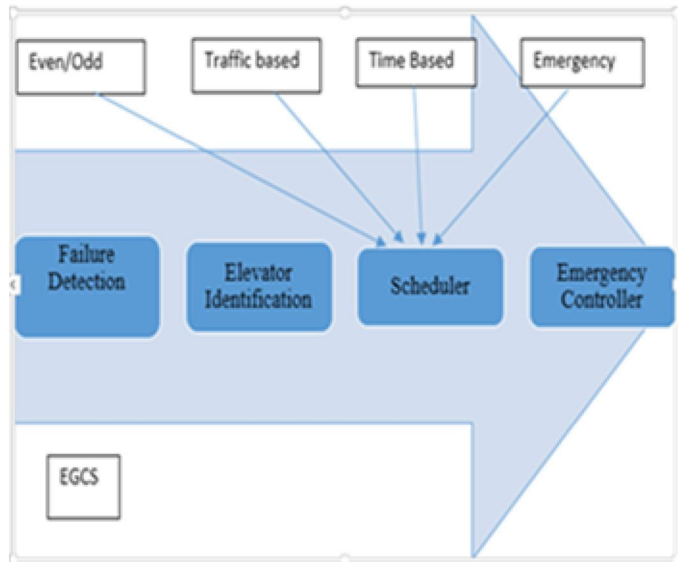

Figure 1: Proposed EGCS block diagram

The same scenario can happen when a marriage or birthday party organized on a particular floor. For more comfort and to diminish the waiting time of guests, the family can book the number of elevators on function for floor/level for the specific time and date. Therefore, the administrator can book the elevators to the demanded floor on the demanded schedule. Once the period over, the scheduling will be regular.

Figure 1 shows the components of the proposed EGCS. The fault detection module is responsible for the recognition of the failure that occurred in the system. Once the failure is detected, the information is sent to the identification module. This module identifies the number and ID of the failed elevator. By using this information, the EGCS calculates the count of working lifts. Scheduler does elevator allocation based on installed scheduling algorithms, working elevators, and failed elevators. Emergency controller dispatches elevators to respective destinations according to new assignments received from the scheduler.
Figure 2 shows the working of EGCS. The EGCS receives a failure signal and detects the failure elevator count and ID, and using this information reschedules the elevators.

In a building with even-odd scheduling, people may cause inconvenience if one of the elevators stops working. The failure occurred in even-odd elevators increases the waiting time of passengers. Consider a building with twenty floors/stories and four elevators installed with an even-odd scheduling approach. Elevators 1 and 3 are odd and supposed to serve odd levels of the building. Elevator 2 and 4 are even elevators assigned to serve even floor services. Consider a situation where an odd elevator stops working. People who wish to move on odd floors face tremendous problems, as there is only one odd elevator in service. The passengers either need to wait for the arrival of an odd elevator, or ride the even elevator, reach even floor and climb up or down to the expected destination floor. This practice usually not good, as many passengers need to wait for an elevator, and it may not be possible to climb staircases to most of the passengers. If the hospital or school located on an odd floor, then it leads to very risky situations, as there may be an emergency in the hospital.

Consider another situation; elevator 1 and 3 fails; people wish to move on odd floors face many problems as odd elevators stopped working. Similarly, if elevator 2 and 4 fail, it causes problems for people who want to proceed on even floors.
To handle such types of situations, when one or more elevators stop working, there is a need for dynamic rescheduling of lifts. The proposed system suggests the reactive risk management technique to handle emergency conditions that may occur in even-odd scheduling. The proposed elevator scheduling methodology is as follows.
Count of Elevators – N, Number of failed elevators – m, working elevators –n, even elevators E
Odd elevators O, Normal Elevators W
n= (N-m),
E=n/2,
O=n/2,
W=n%2

In a building with time-specific floor priority scheduling, school/office positioned on the 10th floor. EGCS allocates n-1 elevators to serve the 10th floor and one elevator to assist all floors. People face inconvenience if one of the elevators stops working. The projected system allocates three elevators E1, E2, E3 to 10th floor during school/office opening & closing time, and fourth elevator E4 as a normal elevator. If one of the elevators from E1, E2, and E3 shuts down, it's working; then, two elevators will be available to serve the school or office floor and one elevator to assist all floors. This situation will not affect the overall performance of the system, as all passenger's requests get satisfied.

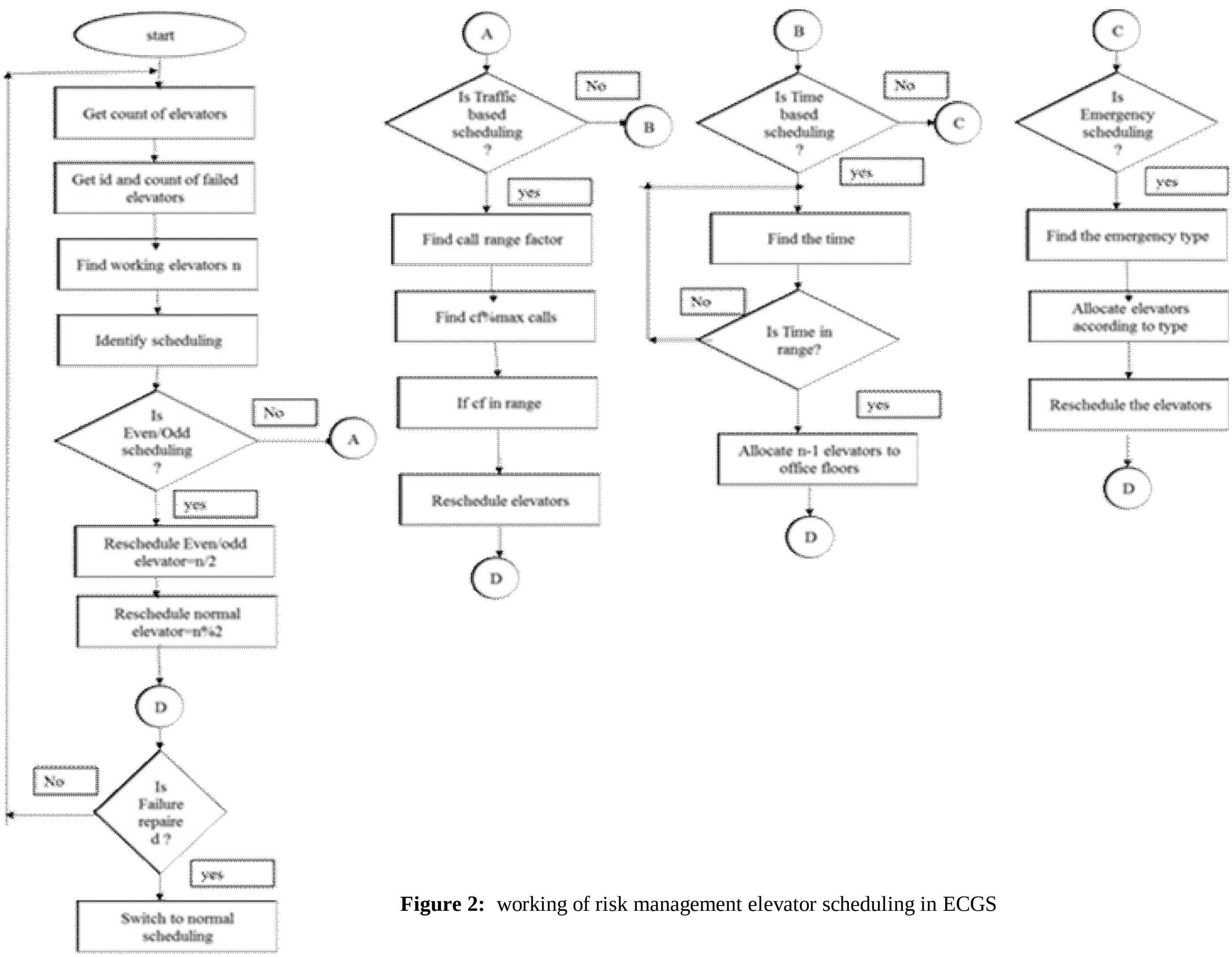

Figure 2: working of risk management elevator scheduling in ECGS

If E4 stops working, this causes incontinence to people those wish to go to intermediate floors. As during morning and evening time E1, E2, E3 dedicatedly allocates to the 10th floor, these elevators are not accessible to passengers.
The passengers need to wait for time over and availability of elevators or climb the staircases to move at the required destination. Both solutions are not acceptable as it results long wait, and not all the passengers can climb the stairs.

The suggested system to handle emergency conditions occurred in a time-based scheduling approach: reschedules n-1 elevators to 10th floor and one as a regular elevator.

In a building with traffic based floor priority scheduling, shopping malls located on 10th, 15th, and 17th floors. EGCS finds the call range and allocates elevators. People face inconvenience if one of the elevators stops working. The proposed system allocates three elevators E2, E3, E4 to 10th and 17th floor, all four elevators to 15th floor, and E1 elevator to remaining floors as per the intensity of incoming calls. If E1 stops working, this causes incontinence to people those wish to go to intermediate levels. The people cannot use the E2, E3, and E4 to travel on intermediate floors as these elevators are explicitly allocated to the 10th, 15th, and 17th floor.

In an emergency (Fire or Flood or Bomb attack at floor), do not use lifts use staircase is the todays scenario. The people need to climb the stairs to reach the destination, but not all the passengers can climb the stairs [29].

In an emergency scheduling like a bomb threat detection, Flood prediction, and fire detection at a particular floor, the EGCS calculates the required trips to perform on the affected floor and accordingly allocates the elevators to the affected location for the evacuation of human's stuck on the floor. If some of the elevators fail or may be booked for function, then the overall scheduling fails to the effective evacuation of the passengers from the affected floor. Number of trips are derived by formula-

$$N_t = P_i \div C$$
$$C = N_e \times C_e$$

Where

C - Total passenger capacity of the elevator,
Ne – Total floors in the building,
N_t - Number of required trips,
N_p – Total Passenger count,
P_i - Passenger count at each floor

When the elevator fault occurs the proposed system finds working elevators 'n' and calculates the number of trips required evacuating the people from respective floors.

The scheduling of elevators during emergencies is as shown in table 1. The building with 20 floors and 4 elevators considered in the simulation.

Table 1: Emergency scheduling of the elevators [29]

Sr.No.	Threat type	Floor affected	Population	Elevator allocation	From floor	To Floor	Trips
1	Fire	10	300	4	10	6	5
2			300	4	11	7	5
3			100	2	12	8	4
4			100	2	9	4	4
5	Bomb	10	300	4	10	6	5
6			300	2	11	15	10
7			100	2	9	5	4
8	Flood	1	100	4	1	4	2
9			100	2	2	5	4
10			50	2	3	6	2

The proposed system provides a solution by detection of working elevators and rescheduling of available elevators for emergency evacuation.

4. RESULTS

A building with ten elevators has five even and odd elevators. Table 2 shows the scheduling in the even-odd system and dynamic reconfiguration during the failure of the elevators. The simulation consists of a 20-floor building, and four elevators and results are calculated accordingly.

Table 2: Even-odd dynamic reconfiguration during failure of the elevators

Fail Ele	Failed Elevator ID	Even odd system			Proposed system			
		Even	Odd	Normal	Working	Even	Odd	Normal
0	-	5	5	0	10	5	5	0
1	E1	5	4	0	9	4	4	1
2	E1,2	4	4	0	8	4	4	0
3	E1,2,3	4	3	0	7	3	3	1
4	E1,2,3,4	3	3	0	6	3	3	0
5	E1,2,3,4,5	3	2	0	5	2	2	1
6	E1,2,3,4,5,6	2	2	0	4	2	2	0
7	E1,2,3,4,5,6,7	2	1	0	3	1	1	1
8	E1, 2,3,4,5,6,7,8	1	1	0	2	1	1	0
9	E1,2,3,4,5,6,7,8,9	1	0	0	1	0	0	1
10	E1,2,3,4,5,6,7,8,9,10	0	0	0	0	0	0	0

Table 3 shows the Time based dynamic reconfiguration during the failure of the elevators and the time-based elevator scheduling. In the emergency scheduling, if one of the elevator fails then EGCS finds the working elevators, calculates the required number of trips and performs the elevator scheduling.

Table 3: Time based dynamic reconfiguration during failure of the elevators

Failed Elevator	Failed Elevator ID	Time-based system		Proposed system		
		10th Floor	Normal	Working Elevator	10th Floor	Normal
0	-	3	1	4	3	1
1	E1	2	1	3	2	1
2	E1,2	1	1	2	1	1
3	E1,2,3	0	1	1	0	1
2	E1,E4	2	0	2	1	1
1	E4	3	0	3	2	1
2	E2,E4	2	0	2	1	1

Table 4: Traffic based dynamic reconfiguration during failure of the elevators

Floor No	No. of calls	Traffic-based scheduling	Proposed system Elevator Allocation			
			E1 fail	E2 fail	E3 fail	E4 fail
1	23	E 1	E2	E1	E1	E1
2	16	E 1	E2	E1	E1	E1
3	12	E 1	E2	E1	E1	E1
4	15	E 1	E2	E1	E1	E1
5	16	E 1	E2	E1	E1	E1
6	20	E 1	E2	E1	E1	E1
7	10	E 1	E2	E1	E1	E1
8	29	E 1	E2	E1	E1	E1
9	23	E 1	E2	E1	E1	E1
10	200	E 2, E 3, E 4	E 3, E 4	E 3, E 4	E 2, E 4	E 2, E 3
11	18	E 1	E2	E 1	E 1	E 1
12	17	E 1	E2	E 1	E 1	E 1
13	22	E 1	E2	E 1	E 1	E 1
14	24	E 1	E2	E 1	E 1	E 1
15	269	E 1, E 2, E 3, E4	E 2, E 3, E 4	E 1, E 3, E 4	E 1, E 2, E 4	E 1, E 2,E3
16	24	E 1	E2	E 1	E 1	E 1
17	187	E 2, E 3, E 4	E 3, E 4	E3, E 4	E2, E 4	E2, E 3
18	17	E 1	E2	E 1	E 1	E 1
19	16	E 1	E2	E 1	E 1	E 1
20	25	E 1	E2	E 1	E 1	E 1

The proposed system to handle emergency conditions in a traffic priority system gives results as table 4. Results show that emergency scheduling during elevator failure gives better results as compared to regular scheduling.

To handle emergencies the risk management EGCS shows the results as per the table 5.

Table 5: dynamic reconfiguration during failure of the elevators to handle emergencies

Sr .No.	**Threat type**	**Floor affected**	**Elevator allocation**	**1 Elev fail**	**2 Elev fail**	**3 Elev fail**	**4 Elev fail**
1	Fire	10	4	3	2	1	0
2		11	4	3	2	1	0
3		12	2	2	1	1	0
4		9	2	1	1	1	0
5	Bomb	10	4	3	2	1	0
6		11	2	2	1	1	0
7		9	2	1	1	1	0
8	Flood	1	4	3	2	1	0
9		2	2	2	1	1	0
10		3	2	1	1	1	0

The results shows that the risk management EGCS gives best results to handle the risks occurred due to elevator failure by rescheduling the working elevators. The system reduces people inconvenience, as they need not to wait for elevators and can use rescheduled elevators.

5. CONCLUSION

The proposed study focuses on elevator rescheduling in EGCS with proactive and reactive risk management techniques. The proposed EGCS handles the situations that may occur due to the elevator shut down and hiring elevators. The proposed system presents an innovative approach for the elevator rescheduling in case of elevator failure. If one of the elevators fails due to any of the reasons, then the proposed elevator scheduling reconfigures the installed elevator system and reallocates the bins. The results generated gives better elevator allocation and reduces passenger inconvenience.

REFERENCES

1. Xie Jiaping, Tao Fei, et al. **Intelligent Elevator Safety Detection System Based on Cloud Service Big Data**, *International Conference on Advances in Computer Technology*, *Information Science and Communications* 2019, pages 251-256 ISBN: 978-989-758-357-5.
2. Changxi Han, Min Zhang et al. **Research of Elevator Security Data Mining Based on Hadoop**, *Chinese Control and Decision Conference (CCDC)*, 2019, 978-1-7281-0106-4/19.
3. Jin-Xi Zhang, Guang-Hong Yang. **Supervisory switching-based prescribed performance control of**

unknown nonlinear systems against actuator failures, *International Journal of Robust Nonlinear Control* 2020; 1–19.
https://doi.org/10.1002/rnc.4878

4. Alejandro Duarte Suarez, et al. **Design of an Elevator Monitoring Application using Internet of Things**, *International I Journal J of Applied Engineering E Research R*, Volume 13, Number 6 2018, pp. 4195-4202.
5. Zihan Ming, et al. **Elevator Safety Monitoring System Based on Internet of Things**, *International Journal of Online Engineering* Vol. 14, No. 8, 2018.
6. Juanjuan Li. **Research on Internet of Things Elevator Fault Detection and Automatic Alarm System Based on Android**, *Advances in Computer Science Research, third International Workshop on Materials Engineering and Computer Sciences*, volume 78 2018. https://doi.org/10.3991/ijoe.v14i08.9179
7. Mihailo Isakov, Ahmad Patooghy et al. **Advertiser Elevator: A Fault-Tolerant Routing Algorithm for Partially Connected 3D Network-on-Chips**, *IEEE 60th International M.idwest Symposium on Circuits and Systems* 2017.
8. Ronak Salamat, et al. **Resilient Routing Algorithm with Formal Reliability Analysis for Partially Connected 3D-NoCs**, *IEEE transactions on computers*, vol. 65, no. 11 November 2016. https://doi.org/10.1109/TC.2016.2532871
9. Charles P. Shelton Philip Koopman. **Developing a Software Architecture for Graceful Degradation in an Elevator Control System**, *Workshop on Reliability in Embedded Systems*, October 2001.
10. Yun-Young Choi, et al. **A Nine-Phase Permanent-Magnet Motor Drive System for an Ultrahigh-Speed Elevator**, *IEEE transactions on industry applications*, vol. 48, no. 3, **May/June 2012.** https://doi.org/10.1109/TIA.2012.2190472
11. **B. D. Petrovic, G. S. Nikoli. Software Tool for Distributed Elevator Systems**, *scientific publications of the state university of Novi Pazar ser. A: appl. Math. Inform. And mech*. Vol. 3, 1, 43-51, 2011.
12. Seung-Tae Park and Bo-Suk Yang. **An implementation of risk-based inspection for elevator maintenance**, *Journal of Mechanical Science and Technology*, 2367-2376, 2010. https://doi.org/10.1007/s12206-010-1004-1
13. Zhang Guangming, et al. **The Study of Elevator Fault Diagnosis Based on Multiagent System**, *International Conference on Computational Intelligence and Software Engineering*11-13 Dec. 2009.
14. Hajime Yamashina, Shunsuke Otani. **Optimal preventive maintenance planning for multiple elevators**, *Journal of Quality in Maintenance Engineering*, Vol. 7 No. 2, 2001, pp. 128-150. https://doi.org/10.1108/13552510110397430
15. Gang Niu, Sun-Soon Lee, et al. **Decision fusion system for fault diagnosis of elevator traction machine**, *Journal of Mechanical Science and Technology*, 2008, 85-95.
16. Ying Huang, Weijia Yu. **Elevator Safety Monitoring and Early Warning System Based on Directional antenna transmission technology**, *ELECTRONICS*, VOL. 19, NO. Two, DECEMBER 2015. https://doi.org/10.7251/ELS1519101H
17. Husson et al. E**levator system**, *United States Patent (19*) 4,162,719 Jul. 31, 1979.
18. Sakata et al. E**levator control system**, *United States Patent* 4,350,225 Sep. 21, 1982.
19. Auer et al. **Two-way ring communication system for elevator group control**, *United States Patent*, 5202,540 Apr. 13, 1993.
20. Polis et al. **Multiprocessor supervisory control for an elevator system**, *United States Patent* 4,567,560 Jan. 28, 1986.
21. Blain et al. **Elevator system adaptive time-based block operation,** *United States Patent* 4,766,978 Aug. 30, 1988.
22. Kaneko et al**. Elevator control system**, *United States Patent* 4,345,670 Aug. 24, 1982.
23. Meguerdichian et al. **Elevator car and riser transfer**, *United States Patent* 5,272,287 Dec. 21, 1993.
24. Bo Xiong, Peter B. Luh, Shi Chung Chang. **Group Elevator Scheduling with Advanced Traffic Information for Normal Operations and Coordinated Emergency Evacuation**, *Proceedings of the International Conference on Robotics and Automation*, Barcelona, Spain, April 2005.
25. Peter B. Luh, Bo Xiong, and Shi-Chung Chang. **Group Elevator Scheduling with Advance Information for Normal and Emergency Modes**, *Transactions on automation science and engineering,* vol. 5, no. 2 April 2008. https://doi.org/10.1109/TASE.2007.895217
26. M. D. Sale, V. Chandra Prakash. **Elevator Group Control System: scheduling of elevators using even and odd elevators approach**, *JARDCS Journal of Advanced Research in Dynamical and Control Systems*, issue 18, 3231-3242, 2017.
27. Malan Sale, V.Chandra Prakash. **Traffic-Based Floor Preference for the Scheduling of Elevators in Elevator Group Control System**, *Indonesian Journal of Electrical Engineering and Computer Science*, Vol. 16, No. 2, November 2019, pp. 835-842. https://doi.org/10.11591/ijeecs.v16.i2.pp835-842
28. Malan Sale, V. Chandra Prakash. **Dynamic Dispatching of Elevators in Elevator Group Control System with Time-Based floor Preference**, *International Journal of Recent Technology and Engineering*, ISSN: 2277-3878, Volume-7 Issue-5, January 2019.

M. D. Sale, V.Chandra Prakash. **Elevators Scheduling in Elevator Group Control System for the Emergency Evacuation of High Rise Buildings**, *International Journal of Scientific & Technology Research*, volume 8, issue 12, December 2019.