Assessment of Intelligent Solutions for Improving Elevators' Performances

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A General Survay

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Abstract: In the process of introduction of information as well as data capabilities the first approach is adding technology that can be used in many spheres for buildings and upgrading apparatus and utensils. However the focus of this study is on the deficiency of current elevators associated with efficiency and debugging of the errors or security systems where we concentrate on the introduction of new trends which advise that elevators should be implemented with intelligent devices. Smart elevators easily provide means to predict and prevent errors and bring the chances of an error to a minimum. Needless to say is that a range of negative effects are unavoidable when it comes to the introduction of new technology. This paper will illustrate both the advantages and the disadvantages of using intelligent devices in elevators and through an analysis of the various options using Multi Criteria Analysis method perform ranking of the presented solutions.

Keywords: elevator, intelligent technology, The Multi-Criteria Decision-Making (MCDM).

Introduction

Nowadays, the design of buildings calls for architectural, civil and mechanical skills, resulting with no universally accepted definition of 'smartness' or 'intelligence' in this domain [7, 12]. However in our everyday performance a key essential element is the utilization of smart devices due to the fast path of technological expansion. Consequently the world of technology changes into advancement and improvement while peoples' needs become more complex. Meanwhile the needs become somewhat a paradox to itself while the necessity of better quality, higher speed or even effectiveness features require meeting the criteria of eco-solution at the lowest cost [2].

The paper will focus on smart ready technologies which are connected with the elevator operation as well as automatic rescue devices for elevator [4, 7]. The smart technologies referenced in this study improve the operation of the elevators in the following areas [13, 14]:

1. increase energy efficiency and comfort,
2. facilitate the management and maintenance and
3. increase the security.

Related to the idea of using elevators in some buildings and making a building economical and efficient, the main goal of this paper is to give a direction to choose the right elevator smart technology for a given building, through an analysis of the various options using Multi-Criteria Analysis method (MCA) to provide the best solution [9, 10].

An overview of smart technologies

A PLC control table

A control system of an elevator has a key purpose to administer movements of an elevator in response to the user's requests. The electric driving system includes the following: elevator car, the traction motor, door motor, brake mechanism, relevant switch circuits. Throughout developing a new system, programmable logic controllers (PLC) are used to change the numerous relays [5].

Nowadays, control signals of the elevators are mainly realized by PLC. The PLC collects data from the sensors or the input devices, processes them, and after that generates outputs which are based on pre-programmed parameters while being compliable just about any application.

The foundation of PLC control table structure is explained in the next section with an example to simplifyand demonstrate the key idea. The logic function of the way an elevator operates consists of the following steps:

1. When a person enters, light/ fan switch ON automatically;
2. The door is closed, motor is switched ON and brakes are free;
3. When the floor is reached the limit switch of the particular floor gets activated and switches OFF the motor;
4. When none of the floor call switches are pressed up to 40 seconds time duration, then elevator's cabin fan and light will automatically be switched OFF which will save electricity;
5. When a STOP button is pressed the cabin fan will still function and the lights will be ON as well;
6. What permits the elevator to function as well as before an error occurred in case of power crash is that the PLC remembers the progression of the last status.

Rescue Device for Elevator

Among other things, one of the main goals of elevators is to guarantee security even during failure of main power supply. Every time there is a power defect in the elevators where there is a supply of power shortage or damage there is a device for rescue in the system especially designed for this kind of emergencies. Consequently, this device is designed for the case having people in the elevator, having their safety a priority. In the system presented in [10], about 12 batteries of 12V each in series-parallel relation are used as a source for the Uninterruptible Power Supply (UPS) system. In the next section we have depicted through a diagram how this system is functioning (Figure 1, Figure 2). Overall, there are seven stages in the process, beginning with "I" and the "P" signals (the "I" stands for an electrical current signal and the "P" stands for a pneumatic or pressure signal). Moreover, in order to start "I"/ "P" needs a signal that is required to be distributed. After the signal is distributed it is utilized in splitting the procedure of opening and closing the door. A sensor assists in this process. During normal running through the main power supply the aim is to turn the motor in mode of OFF. Opposite, failure of main power supply should switch off other sensors and active ground floor sensor.

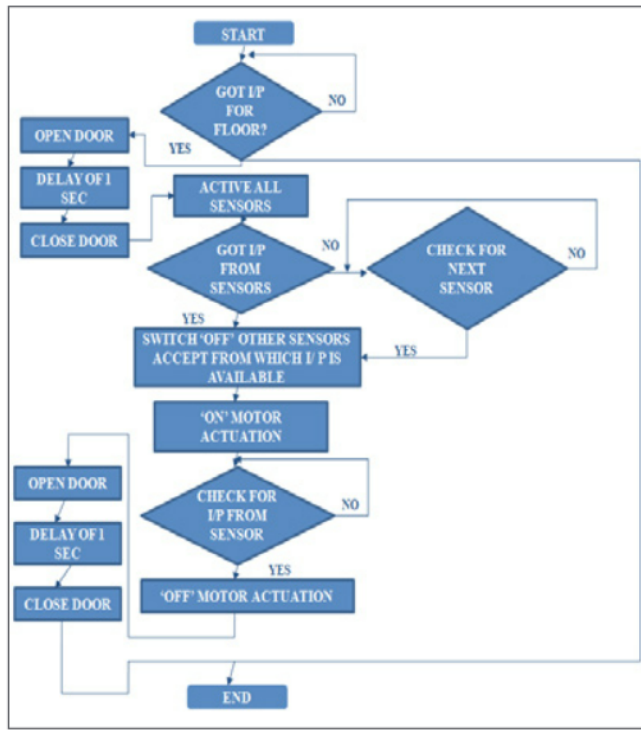

Figure 1. *Flow chart of elevator during normal running through main power supply*

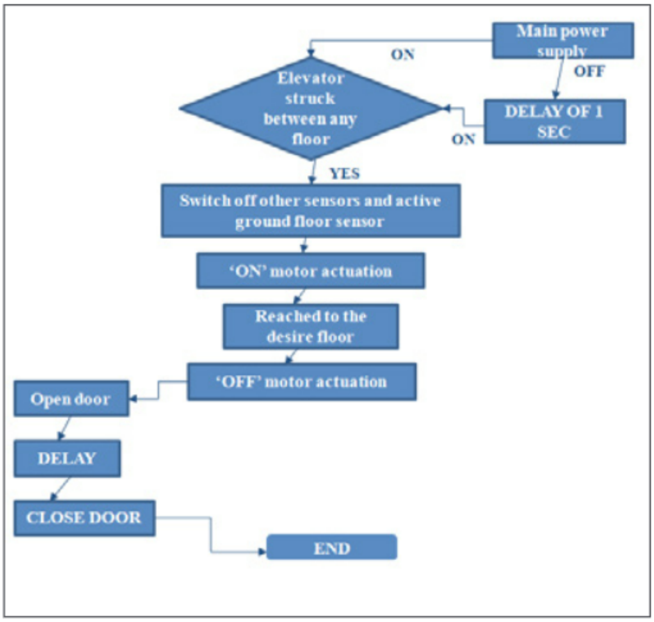

Figure 2. *Flow chart of elevator during failure of main power supply*

Some of the disadvantages of using battery as a source in this device are listed in [10]:

1. To avoid reducing the life of a battery, to use fully charged provision has to be made after the battery has fully charged and at the same time it is necessary to take in consideration that after the battery is completely full it still needs to be held in charging mode.If the battery takes longer time to be charged means that the system cannot function till the battery is fully charged;
2. The investment is expensive.

Accordingly, electrolytic capacitors have been taken as an example in this paper that can be applied as a foundation in case where there is battery replacement needed in various systems where a restricted period power supply is needed.

The advantages of electrolytic capacitors opposed to the battery are:

1. Electrolytic capacitors don't need any supply after they are fully charged because they stop current when they are charged;
2. A lesser amount of time versus the actual time for charging the battery;
3. Investment of electrolytic capacitors is much less than the cost of battery for the same ratings. However the repair cost of the capacitors is not as high as the costs for repair of the battery.

Research on the elevator door control system based on the image processing technology

As passengers, we tend to ignore the role of security until something goes wrong, but we tend to notice the elevator's speed and the driving time. For instance, most passengers are frustrated by spending up most of the time waiting for the elevator. So, in a case where the elevator has to come down from floor A to another floor and if the average weight of the persons waiting for the elevator in the another floor be more than the relation B-w, then there is no point to put down the elevator to that floor because the elevator will give an overload notice at the time the person that is down on the floor enters the elevator (Figure 3). The problem is that not everyone will be serviced and a few people will not be able to enter the elevator while waiting for another one to arrive and pick them up.

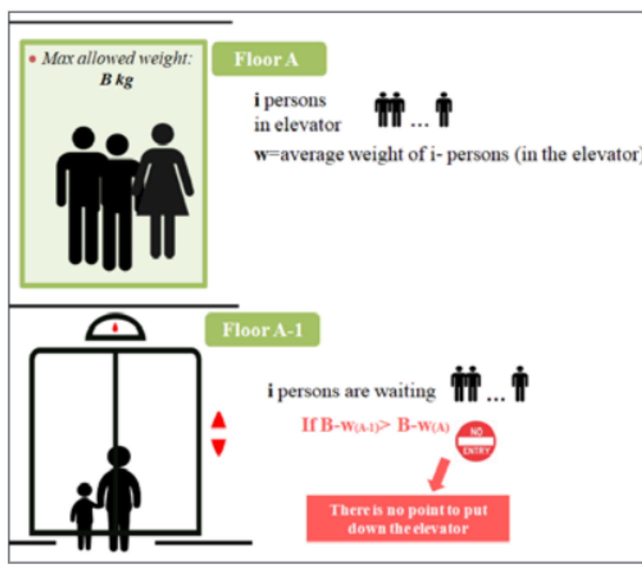

Figure 3. *Elevator control system based on the maximum allowed weight*

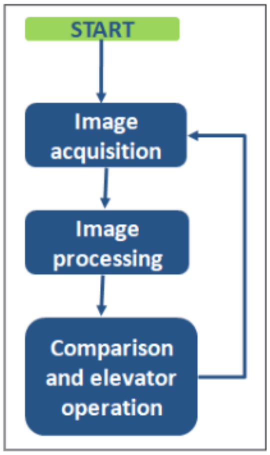

Figure 4. *Flowchart of the flow of operation in the proposed technique*

On Figure 4 a technique is shown that is proposing a stream of different operations while each part is explained in details in [9].

1. Call button: The call button follows a First In First Out (FIFO) queue, meaning the person who pressed the call button first will be served first. However there are cases where elevators cannot be used, like for example earthquakes; fires etc,but there may be a few instances of high priority calls. In these cases a separate emergency high priority button can be used to select floors. These high priority elevators can be managed by the same hardware but a separate row can be used that is marked with the highest priority [14].
2. Image Acquisition: A video camera feed continuously notes the activities that occur in the elevator hallway. It is positioned in a way where it observes the call button as well as a part of the elevator hallway. Consequently, the positioning of the camera is determined due to the need to monitor the area where people are expected to stand and wait for the elevator. Snapshots can be taken in the moment when a call button is pressed.
3. Image Processing: There will be a video camera running covering the hallway of the elevator. When the call button is pushed the camera will capture an image of the corridor as well as the people waiting for the elevator. In order to keep track of the number of people in front of the elevator it is necessary to use edge detection method while image is processing.
4. Comparison: The final output archived from the image processing module is a value that concurs with the number of white pixels that are given in the image [13].

Ranking the smart implementation using MCDM methods

The Multi-Criteria Decision-Making (MCDM) methods are a significant prospective instrument in order to analyze difficult situations since their innate nature to review different choices like for example scenarios, strategies or policies, while utilizing a range of criteria in order to select the best-suitable alternative or alternatives [1]. Consequently in order to get to the final performance we need to further more analyze these alternatives. In this research paper, the method Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used. The fundamental conception of TOPSIS method is that the selected alternative should have the shortest geometric distance from the ideal solution and the farthest geometrics distance from the negative-ideal solution. In this paper we will apply TOPSIS to find the best alternative for smart investment in elevators by using an example.

The TOPSIS method

The TOPSIS method procedure consists of series of steps [11]. Table 1 contains the performance of the evaluated alternatives, which is the starting information for the TOPSIS calculation.

Table 1. *TOPSIS information*

Alternatives	Criteria			
	C_1	C_2	...	C_j
A_1	X_{11}	X_{12}	...	X_{1j}
A_2	X_{21}	X_{22}	...	X_{2j}
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
A_i	$_{i1}$	X_2	...	x_{ij}
W	W_1	W_2	...	w

Where [1]:
A1, A2, … , Aj represent possible alternatives among which a decision maker has to choose,
C1, C2, … , Cj are criteria with which alternative performance are measured,
xij is rating of alternative Ai with respect to the criteria Cj,
wj is the weight of the criteria Cj,
i=1, … , m is the number of alternatives,
j=1, … , n is the number of criteria.

When some of the criteria are shown as the qualitative values, they need to be changed into quantitative values. We conducted a survey among maintained service companies. Interviewed people gave the score for three alternatives: Elevator door control system based on the image processing, PLC control table and Rescue Device for Elevator in comparison with four evaluation criteria (C1 C2, C3, C4), using the numerical scale by (Table 2) [8]. The results of the survey are converted into qualitative values shown in (Table 3).

Table 2. *Transformation of linguistic scales into quantitative values*

Linguistic scale	Quantitative value	
	Benefit- max	Cost- min
Very high	9	1
High	7	3
Average	5	5
Low	3	7

Table 3. *Raw data*

	Security	Costs investment	Maintenance cost	Easy to deploy
Alternatives	max	min	min	max
A1: Elevator door control system based on the image processing	5	1	1	3
A2: PLC control table	9	7	5	5
A3: Rescue Device for Elevator	7	5	3	9
weightage	**0.25**	**0.35**	**0.25**	**0.15**

Next, normalized decision matrix (step 1), is obtained by applying formula (1).

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}} \quad (1)$$

In step two, calculation of weighted normalized matrix vij of each criterion is made using the following formula (2):

$$v_{ij} = \overline{X}_{ij} \times W_j \quad (2)$$

Step three performs calculation of the ideal best (3) and ideal worst (4) value [12]:

$$V^+ = (v_1^+, v_2^+, \ldots, v_n^+) = \left[\left(_i \max v_{ij} \mid j \in I\right), \left(_i \min v_{ij} \mid j \in J\right)\right] \quad (3)$$

$$V^- = (v_1^-, v_2^-, \ldots, v_n^-) = \left[\left(_i \min v_{ij} \mid j \in I\right), \left(_i \max v_{ij} \mid j \in J\right)\right] \quad (4)$$

I- associated with benefit criteria;
J- associated with the cost criteria,
i=1, … , m;
j= 1, … , n

In step four, the Euclidean distance from the ideal best (Si+), formula (5), and ideal worst (Si-), formula (6), values are calculated.

$$S_i^+ = [\sum_{j=1}^{m} (v_{ij} - v_j^+)^2]^{0.5} \quad (5)$$

$$S_i^- = [\sum_{j=1}^{m} (v_{ij} - v_j^-)^2]^{0.5} \quad (6)$$

The last step in the implementation of the TOPSIS method is the calculation of Performance Score, Formula (7).

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (7)$$

In the end we perform ranking of the Pi values.

Performing TOPSIS calculation in R

For the purpose of performing TOPSIS calculations, we have used R, which is a state of the art tool widely used for statistical computing and data analysis by a large community [6]. A set of statistical

```
#values of rating matrix Xij
dataTable<- matrix(c(5,1,1,3,9,5,5,5,7,5,3,9),
nrow=3,
ncol=4,
byrow=TRUE)

row names(dataTable) <- c("System based on image processing","PLC control table","Rescue device for elevator")

colnames(dataTable) <- c("Security","Costs Investment",
                         "Maintenance cost","Easy to deploy")
#weight for criteria Cj
weights<- c(0.25,0.35,0.25,0.15)

#criteria min/max for criteria Cj
criteria<- c("max", "min", "min", "max")

names(weights) <- colnames(dataTable)
names(criteria) <- colnames(dataTable)

#calculate Pi ranking
result<- TOPSISVector(dataTable, weights, criteria)
```

Figure 5. *R script for Pi values calculation*

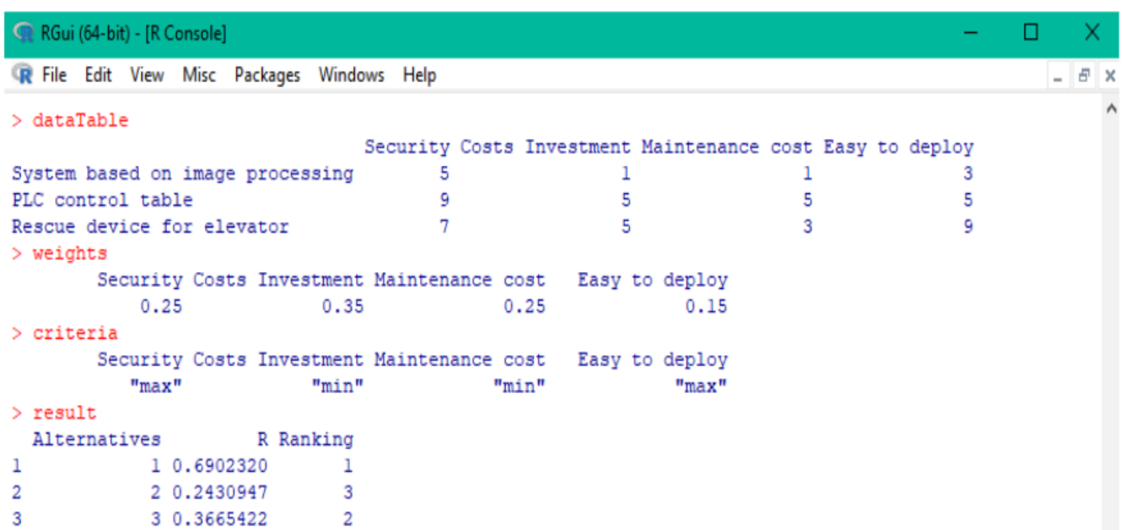

Figure 6. *Executing R script in R console*

techniques are implemented in the base R environment, but a much larger collection of functions are available through packages accessible through the Comprehensive R Archive Network (CRAN) sites.

The above described calculation of performance score is done via a function from the MCDM package for R. The R script presented in Figure 5 is used to obtain the results:

The script is then executed in the R Console. Figure 6 shows the values of dataTable, weights, and criteria, which contain the values for xij, wj and cj respectively, along with the score table for the three alternatives.

Table 4. *Rank of the Pi value*

Pi	Rank
0.6902320	1
0.2430947	3
0.3665422	2

From Table 4, we can conclude that the ideal option, in this general example, is alternative no.1.

This example illustrates the way to make a decision based on MCDM on what is the best option for an investment in the case of the analysis performed in this paper. The process can be further refined and augmented by using more criteria, in order improve the selection of the best option.

CONCLUSION

The development of the proposed systems: elevator control system and security devices can easily reduce shortcoming of today's systems. However we have to take in consideration the opportunity for development in the engineering field.

An overview of all ideas and solutions above ensures high reliability which is one of the most important goals. After applying TOPSIS calculation, we can conclude that the best option is to use elevator door control system based on the image processing. In order to show the exact percentage of the effectiveness of the proposed method, quantitative values that are obtained from the conducted survey are not enough. We need more structured tests for executing the model. Needless to say the needs of the client are above all importance.

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