Improving Communication Systems During Fire Evacuation Procedure at an ANU Hall of Residence

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Executive Summary

This report aims to optimise the fire evacuation procedure at the ANU Hall of Residence, 'Burton and Garran Hall'. The goal of this report is to use design solutions to improve communication throughout the fire evacuation at the hall. This report took a multi-faceted approach, suggesting a range of design solutions. The solutions analysed included new two-way radios, pulsing red lights and a Personal Address System. A large systematic change with proven benefit was the automatic calling of the duty student in the case of evacuation. These designs proved to have many benefits, including a significant decrease in evacuation times, a large decrease in the amount of information delays and losses as well as increased support for disabled residents. The benefits far outweighed the costs of the designs and thus resulted in a low payback period for the client. The client is now advised to look into more specific installation and upfront costs.

Contents

1.0 Background

This report serves to optimise the fire evacuation procedure at an Australian National University (ANU) hall of residence, specifically Burton and Garran Hall, which houses 512 residents across the 16 floors. Each hall at the ANU has their own fire evacuation procedure depending on their number of fire wardens and different areas to evacuate. The client for the system being analysed is the Deputy Head of Hall (Nerilee Flint) and the users are the appointed fire wardens (which I am one of in 2015). The client has given a formal write up of the current procedure and it can be supplied upon request. The client is new to the hall and has identified a number of key issues with the procedure and the goal of this report is to resolve these problems through a design solution and thus improve upon the system. The benefit of improving this procedure is increasing the safety of residents living within the hall of residence.

2.0 System Scoping

The system being analysed in this report is defined in the table below (table 2.0.1). It is worthy to note here, that the fire wardens at the hall of residence are also the duty students (team of 16). The duty students are on call after office hours (4:30pm until 9:30am the next morning) and shifts are on a rotation basis. There is one fire warden per floor, and two duty students on call at all times after office hours.

Table 2.0.1: System Boundary Chart

Included	Excluded
Fire Evacuation Procedure Burton and Garran Hall Use of fire wardens as Duty Students	Level of training of the fire wardens Any other emergency response procedures Number of fire wardens All other halls of residence at the ANU Budget Allocation (within reason) Drill scenarios Alarm response during office hours (9:30am-4:30pm)

The client was met with to discuss the situation and has set a number of parameters for the design solution, these include (Flint, 2015):

- Must adhere to the safety guidelines set by the ANU in accordance with ACT Government (Facilities and Services Division, n.d.)
- No budget has been allocated for the upgrade or improvement of the fire evacuation system, however it can be added into the maintenance budget for future years. Low cost is ideal.
- Must increase the safety of the residents of the hall.

In the meeting with the client, they set the above parameters but also outlined a number of different issues that she would like to see resolved. The issues are as follows:

- Limited support for disabled residents

- Poor communication between wardens and the warden stationed at base
- Slow evacuation times of common areas

3.0 Preliminary Research

3.1 Research Methodology

Preliminary research was undertaken to gain further insight into the system beyond the official written procedure. Qualitative research methods, in the form of surveys were conducted. Sound research methodology as discussed by Brace (2008) was employed, by using good research methodologies the most comprehensive and useful data can be obtained. The survey issued to the fire wardens to complete can be found in Appendix A. Rea and Parker (2005) discuss the advantages of web-based surveys, they are convenient, allow for rapid data collection and are confidential for responders. Some disadvantages of web-based surveys in a general sense include lack of interviewer involvement and a limited respondent base. However these disadvantages are limited in the current scenario as interviewer involvement would introduce unwanted bias (being on a team with them currently could influence their responses) and the number of possible respondents are low however easily accessed by a group Facebook page. A total of 11 responses were obtained from a possible 16 respondents, which was deemed a high enough sample size to be an adequate representation of the views of the current 16 fire wardens (Australian Bureau of Statistics, 2014).

The rationale behind collecting surveys results from the fire wardens is to gain intimate insights into the issues they find most difficult and time consuming in their role. Besides confirming the issues outlined by the client, the users may also present other issues or supply information with regards to a broader issue.

3.2 Preliminary Research Results

There were some very large emergent trends from the data obtained from the surveys. A coding scheme was developed to identify these trends easily. All respondents indicated that there a lot of issues can be attributed to the lack of training of the fire wardens; training of the fire wardens is explicitly not within the scope of this report (refer to table 2.0.1) but is good feedback to provide the client. Issues regarding the drills were also disregarded, as they are not within the scope of this report.

Some questions enabled the yield of quantitative data. 91% of fire wardens indicated that calling the duty student would be useful, with only 1 of the 11 warden respondents indicating that they are 'Unsure if it is useful'. This is an overwhelming response and should be considered in the proposed design solution. Another similarly significant response was the 82% of fire wardens think that the current number of fire wardens is adequate. One response however indicated that *'There is no assurance for more that half of the Senior Resident team to be present during a real fire'* and that *'Training more residents would only increase the probability of having wardens around to help in a real fire.'* While this point was only made by two fire warden responses it is a primary area of concern to be considered in the design solution.

The three largest difficulties indicated in the results from the fire wardens' responses are surrounding the issue of communication, with many indicating that the radio devices used are unreliable, as well as poor resident response generally but especially prominent in common area evacuation. The issue of poor resident response includes such things as residents not evacuating quickly enough or being uncooperative during the evacuation procedure. Common area evacuation was also described by a number of participants, with one indicating that *'Can't hear the fire alarm in most of central! If the kitchen was busy (ie dinnertime) could probably go unnoticed, not loud enough definitely to force people outside.'* With the issue of inadequate alarms, evacuating common areas (referred to as 'Central' by the warden) is difficult and is of concern in this system.

In terms of improvement, the design solution should also consider what the fire wardens find to be time consuming in the fire evacuation procedure. The highest mentioned time consuming task was locking the doors at the end, which was closely followed by communication and the evacuation of rooms. Communication was indicated by the client to be a big issue and is a recurring theme in both the difficult and time consuming aspects of consideration. Furthermore one warden's response gave an interesting idea of having a *'Centralised locking tool where entire blocks can be locked automatically'*.

3.3 Outcomes of the Preliminary Research

The results from the qualitative analysis confirmed the concerns of the client and also gave insight into further areas of improvement within the system, including the response of residents being poor. Quantitative data was also collected from the surveys and gave important feedback, indicating that the number of fire wardens is adequate and also that alerting the duty student would be useful.

4.0 Emerging Design Solutions

4.1 Goals of the Design Solutions

As a result of the preliminary research and the meeting with the client, the following 4 goals of the report have been proposed:

- Additional support systems for disabled residents
- More efficient communication at all stages of the procedure

- Effective evacuation of common areas
- Improved response of residents to the evacuation procedure

A pairwise analysis of the goals has been conducted (see Appendix A for table), yielding the improved communication as the highest priority. The reason behind the support for disabled residents yielding the lowest priority, is due to the fact that none of the fire wardens in their surveys listed disabled support as an issue, whereas the client and the wardens all heavily discussed communication and poor resident response. *As a result of the pairwise comparison, the focus of the report will be on improving communication throughout the fire evacuation procedure.*

4.2 Design Solutions to be Investigated

Several solutions can increase the communication throughout the evacuation. These solutions are brainstormed in the concept generation tree in figure 4.2.1. The designs of peak interest are:

- Personal Address (PA) system
- Pulsing red lights fitted to the alarm units
- Improved radio devices
- Automated calling of the duty student

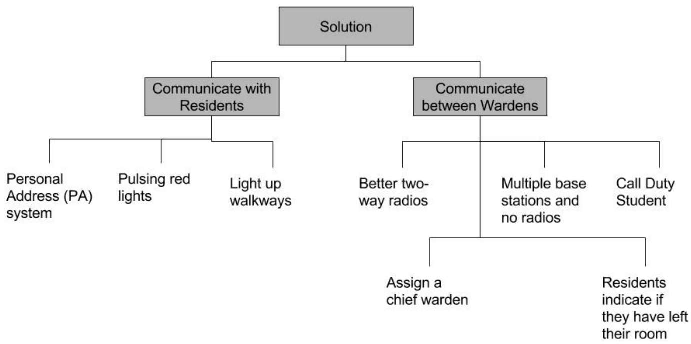

Figure 4.2.1 Concept Generation Tree

In the following analysis, the above-mentioned design solutions will be evaluated in relation to the current system in place. The analysis will include the evaluation of human factors, cost factors, time factors, material factors, the dynamics and control of the system and the energy factors of the system with the new designs. The analysis will be followed by a recommendations and conclusion section for the client to consider.

5.0 Analysis

5.1 Time Factors

Time is a very crucial component for the evacuation procedure. By evacuating quickly and efficiently, lives could be saved and conversely an inefficient system could be putting lives at risk. As identified in the preliminary research section, the most time consuming factors as identified by the fire wardens were the locking of doors at the end, communication and the evacuation of rooms. It was identified by the fire wardens that they do not think that more fire wardens will be useful, so this element will not be considered when attempting to optimise the time of the evacuation response.

Currently, if the alarm sounds, the residents will evacuate as normal, however no fire warden is necessarily contacted, this could add an infinite amount of time to the process. If a fire warden is alerted immediately then the procedure of evacuation can begin immediately. Dealing with uncooperative residents is an issue that is hard to solve, implementing such measures as pulsing lights and the PA system with the alarm sounding system may create a larger sense of urgency and will aim to increase resident response.

All residential room doors and doors in common areas are fitted with special SALTO locks, new software from the company allows the doors to be locked from a central panel. The costs associated with setting this up might be quite large (the website does not detail prices), however the building could utilise this lockdown mechanism in other emergency scenarios (SALTO Government Solutions, n.d.). This type of system was favoured by fire wardens in their responses to the survey and would reduce the time spent securing the building.

A Gantt chart of the new procedure versus the old procedure is shown below in figure 5.1.1. The time saved is clearly highlighted by the improvements made both systematically and through purchased design solutions. The estimated time saved by the new procedure is 6 minutes. That is a very substantial time saving, with the most notable time saving being in the crucial first few minutes of the alarm sounding as the system is run much more efficiently (multiple tasks completed at the same time). The current system was not adequately represented here, as the time for a fire warden to respond could be much longer if none of them hear the alarm sounding (which is likely), the proposed system however is much more reputable as the duty student is automatically alerted.

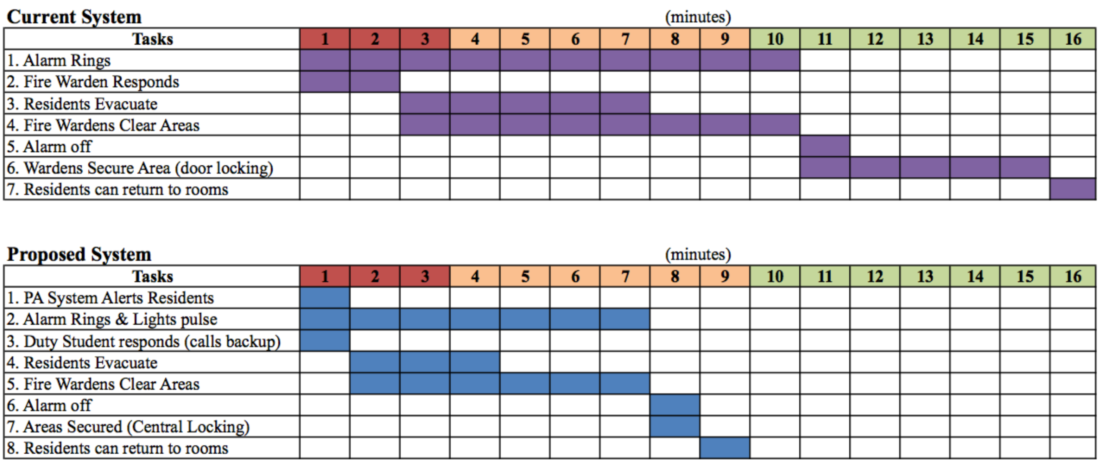

Figure 5.1.1 Gantt Chart for Current and Proposed Solutions

5.2 Cost Factors

The design solutions proposed vary in costs from no upfront costs to relatively high installation, maintenance and upfront costs. The solutions proposed will not generate any revenue for the hall, some indirect revenue may be able to be acquired by increasing rent for residents but this is not within the scope of this analysis. A cost-benefit analysis will be conducted in this report, using rounded estimates. Utilising the theory behind 'Back of the Envelope' calculations, an approximate costing and benefit calculation can be completed (Francis, 1999).

Table 5.2.1: Costs and Benefit Estimates

Upfront Costs		Ongoing Costs (per annum)	
New Two-way Radios (~$100 each, need ~10 sets)	$1000	Extra Energy (lights, radios etc)	$10,000
Lights (~$10 per unit, need ~600 units)	$6000	Extra Maintenance (2 workers extra, 2 full 8 hour days, every six months @ $30/hour)	$2000
PA System	$100,000	Extra Parts (replacing light bulbs, every 5 years)	$1200
SALTO Lock Upgrade	$10,000		
Total:	**$117,000**	**Total:**	**$13,200 per annum**
Benefits (per annum)			
Increased Safety of residents ($1000 per resident, 500 residents)	$500,000		
Time saved	$10,000		
Total:	**$510,000 per annum**		

A payback period graph has been developed and is shown in figure 5.2.1 (right) of the data in table 5.2.1. The graph displays that the crossover of costs and benefits, being the payback period occurs at around 3 months for scenario 1. This is a small payback period, displaying that the benefits far outweigh the costs.

It is important to consider here the benefit estimations. These benefits are all intangible and hard to estimate, thus especially for the largest benefit of 'increased safety of residents'. The estimate of $1000 per resident was determined by the portion of a residents life spent at the hall, this estimate with respect to this context is extremely low. Increasing it beyond $1000 however will make the payback period instant (not realistic). Installation costs were also not included as they have to be conducted by a specific company and these costs are unknown. To investigate the effects further, the rate of benefit was decreased by 50% (scenario 2, figure 5.2.1 left). The payback period doubled, however with still such a large obvious benefit demonstrated in the cost benefit analysis, the benefits seem to always outweigh the costs, resulting in a small payback period, which is ideal.

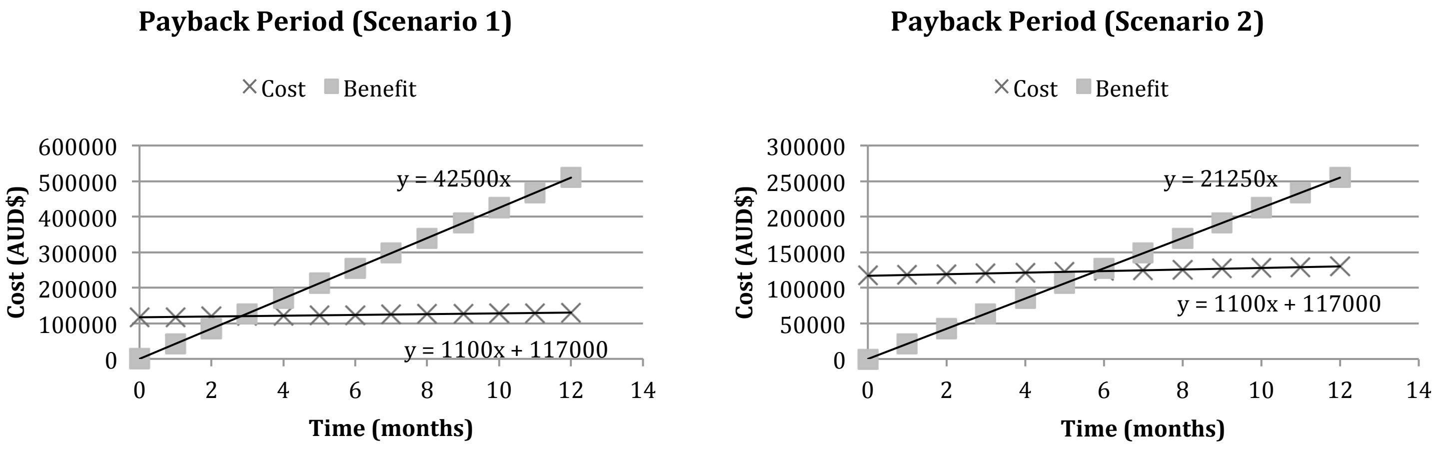

Figure 5.2.1 Payback Period Graph for the Proposed Designs (Scenario 1 right, Scenario 2 left)

5.3 Material Factors

The materials consumed by the proposed designs will need to be analysed in order to determine their impact on the environment and thus if they are worthwhile. For example, are rechargeable batteries better in this context compared to disposable batteries, and also are LED light globes the best value for the job of pulsing light in terms of this setting. Having rechargeable radios is beneficial in many ways, for instance, the need for someone to replace the batteries is now not necessary. Table 5.3.1 below shows a materials audit comparison between rechargeable batteries and regular alkaline batteries.

Emerging from the materials audit, the use of rechargeable batteries is a much better alternative. They need to be replaced less times and have a higher amount of energy. It is also important to consider price. The costs difference of rechargeable batteries versus non-rechargeable batteries in the 'AA' size range is almost negligible. The upfront costs in our scenario are not considered as the devices are recharged on the docking station provided by the radios, this is where the cost difference would otherwise occur between rechargeable and non-rechargeable batteries (as the docking stations to recharge can be quite expensive).

Table 5.3.1: Materials Audit Comparison of Batteries (Unknown, n.d.)

	Total Mass of Cell (g)	Embodied Energy (MJ/kg)	Actual EE (MJ)
Non-rechargeable Alkaline Batteries (AA)	~25	1	0.025
Rechargeable Batteries (Ni-MH)	~25	933	23.325

Another materials audit should also be conducted to analyse the difference between other light globe options and the use of LED light globes. As demonstrated in the materials audit of the light bulbs (table 5.3.2), the LED light globe is the most superior as it by far lasts the longest out of the other two options. Replacing the bulbs will be costly across an estimated 600 units, therefore replacing them less often is ideal. When looking at the cost comparatively, the slightly extra upfront cost of an LED bulb is worthwhile in the long term as replacement costs over the entire hall will far outweigh the benefits of a cheaper bulb if they need to be replaced more often.

Table 5.3.2: Materials Audit Comparison of Light Globes (Ashby, 2014)

	Embodied Energy (MJ/kg)	Bulb Life (h)
LED	35	25000
Incandescent	3.2	1000
Compact Fluorescent	16.3	8000

5.4 Energy Factors

Energy within the system takes many forms and it is beneficial to minimise the losses of energy both electrical and human energy. A Sankey diagram is useful for identifying where energy losses take place, and restructuring using design solutions can help to alleviate these losses. As improvement of communication in the system is the goal of this report it will be beneficial to look at the information flows. This will enable an evaluation of the usefulness of the proposed design solutions. The unit of measurement for the Sankey diagram in our context of information losses is percentage of information provided throughout the evacuation provided. The Sankey diagram in figure 5.4.1 left is for the current evacuation system. The estimations of information throughout the process are justified as follows:

- Communicating to the resident – very minimal, just an alarm sounding, then at the end the fire wardens letting the residents return to their areas (~10%)
- Communicating to the fire wardens – very minimal, again just an alarm sounding, the fire warden has to be in or near the area where the alarm is going off to be alerted (~5%)
- Communicating with the fire department – alarm automatically alerts the fire department (~15%)
- Flow of information from base to fire warden throughout procedure (~40%)
- Information delay (losses): the losses occur if the batteries in the radios do not work, if there is no-one in the area to be alerted of the fire, residents evacuating slowly (~30%)

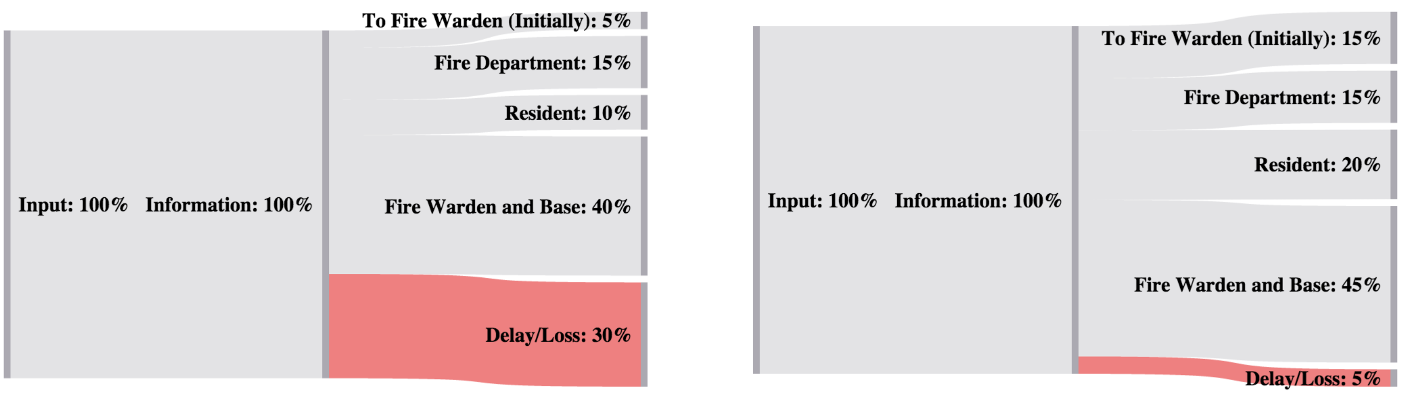

Figure 5.4.1 Sankey Diagram of Information Flows - Left: Current System, Right: Proposed System

It is ideal that the information lost would be very minimal, wasted information indicates inefficiencies within the system. Many of the proposed design solutions help to minimise delays and losses in information flowing throughout the system. For example, the pulsing lights will provide more information to the residents (assisting those with hearing impairments) as well as creating a sense of urgency. Having higher quality and more reliable radio devices will help the fire wardens communicate throughout the procedure ('fire warden and base'). Also more information could be provided to the fire wardens initially through the use of the calling system (where the duty student is alerted when the alarm rings). With these improvements to information flow, losses have been minimalized and the proposed system has the Sankey diagram in figure 5.4.1 right.

5.5 Human Factors

One of the goals identified by the client was to improve support for disabled residents. Whilst this is not needed currently in the system as there are no residents requiring extra assistance, a guest or a resident may in future require extra assistance and the facilities to help this resident or guest should be available. To meet these requirements, two additional design solutions need to be investigated by the client to aid disabled residents. An 'Evac-Chair' is suggested to be purchased by the client, only one chair is necessary and could be stored at the primary base location (central block). The chair being used is shown in figure 5.5.1 (left) below. Furthermore, the 'Evac-Bracelet' is also suggested. If a resident is found to be in trouble, time is wasted by communicating this with the radio devices, instead the fire warden can press the 'assistance needed' button whilst applying necessary first aid. The bracelet also has a light feature (which may be useful if power is lost to the building). The bracelet is pictured in figure 5.5.1 right.

Another assistive feature in the design solutions is for hearing impaired residents, which is the installation of pulsing red lights. These red lights pulse whilst the alarm is sounding and could be used to raise awareness of fire evacuation to these residents and come highly recommended by the Australian Network on Disability (Australian Network on Disability, 2015). The PA system will also be used to greatly enhance communication, by being able to communicate more with vision impaired residents as well as residents who do not have a disability. The location of the fire or dangerous area could be made known which would help residents evacuate more safely. Other aids such as colour coding of doors and exit pathways have been shown to improve evacuation of people with cognitive impairments (Australian Network on Disability, 2015).

Figure 5.5.1 'Evac-Chair' (left) and 'Evac-Bracelet' (right) (Accumax, n.d.)

5.6 Dynamics and Control Factors

In order to analyse the systems dynamics and control a feedback structure will be developed (Astrom and Murray, 2009). Currently the individual fire alarm detectors are fitted in each residential bedroom and in the hallways. These detectors are connected to a main fire panel, when the detector notices a change (i.e. a potential fire), it sounds a beeping noise locally to alert the residents within the area to attempt to resolve the issue. If the issue is not resolved within 3 minutes, then the whole building alarm is set off, causing everyone within the building to evacuate. The fire panel is able to describe where the fire originated from (to assist the fire wardens and the fire department). The current system of evacuation is generalised for the fire wardens as a fire could originate in any location. This information is summarised into the feedback structure shown in figure 5.5.1. Note in the figure, the displaying of location is an output (blue) and the system reset is an input (red). The feedback loop assumes that after the 3 minute period there is no change (i.e. the fire is still present).

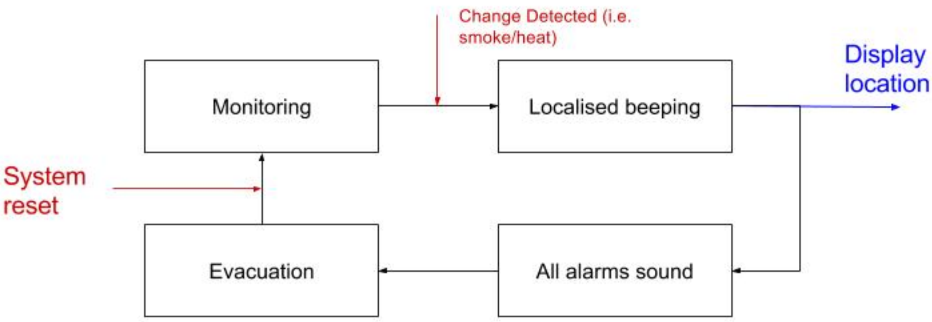

Figure 5.5.1 Feedback Loop of Current System

The goals of our system include increasing communication and increasing resident response. Adding more control mechanisms and systems into the feedback structure will allow for the risk during evacuation to be minimised, as decision making for the residents is assisted. The pulsing red lights, the calling of the duty student and the PA system have been incorporated into the feedback structure and the proposed system is shown in figure 5.5.2.

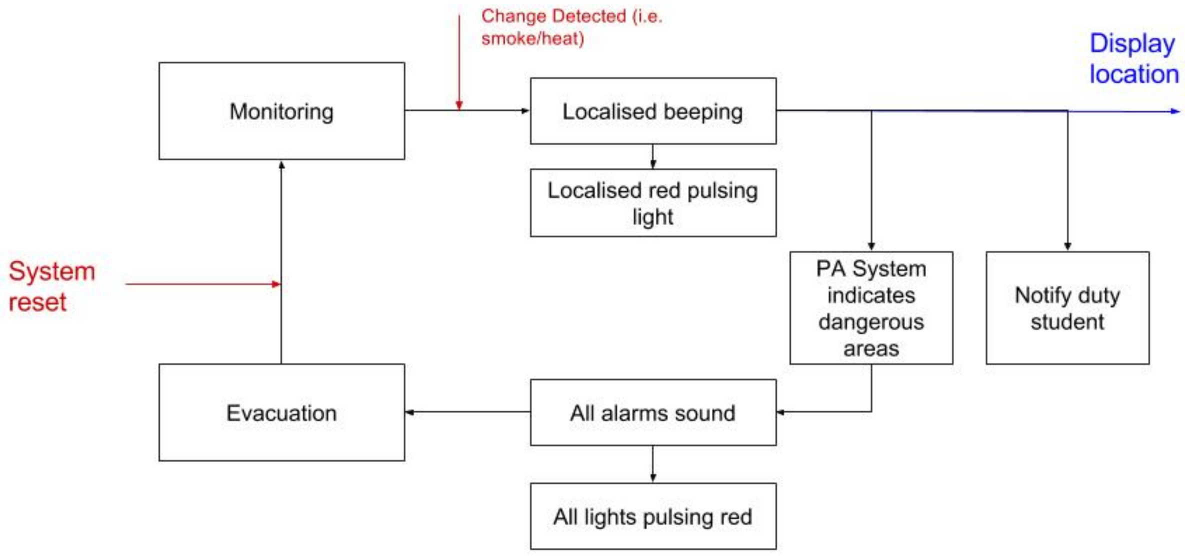

Figure 5.5.2 Feedback Loop of the Proposed System

The PA system is an emergent design solution that provides quite substantial communication to the residents; while its cost and practicality have not been thoroughly analysed it may be worth further investigation by the client. As you can see from the feedback structure, the pulsing red lights are activated when the alarm is sounding (that is the circuit would be completed when the alarm is sounding thus delivering electricity to the lights, allowing them to turn on). Also one other worthy note, is that the PA system informs residents of what is happening prior to the alarms sounding, this in turn should increase resident response to evacuation. Once the PA is finished its pre-recorded announcement, the alarms begin to sound.

As demonstrated in figure 5.5.2 proposed designs are easily implemented into the feedback loop of the system. While the system is now more complex, an added level of control is evident. By increasing the amount of control within the system, that is being that residents (including those with disabilities) are communicated with, the risk to the residents is minimised. The fire wardens are similarly adequately notified and thus evacuation can commence, this procedure is much more streamlined and eradicates the issue of a fire warden not being present in the area requiring evacuation.

6.0 Recommendations

It is recommended to the client that they implement the calling of the duty student automatically, install the pulsing red lights (LED as identified in the materials audit) and purchasing new rechargeable radio devices (rechargeable also recommended from the materials audit). The personal address system is highly recommended also due to its large improvement to communication, however it is important to note that it has the highest upfront and ongoing costs. The benefits it provides do far outweigh these costs, and it could be utilised in other ways (e.g. general announcements and other emergency situations). Furthermore, the human factors section outlined the lack of support for disabled residents in terms of communication. A few recommendations were made in this section which should be considered by the client, these include purchasing an 'Evac-Chair' and even sets of 'Evac-bracelets). Implementing other measures, which are far less costly include colour coding of doors and exit pathways which will assist people with cognitive impairments.

7.0 Conclusions

Through the analysis conducted it has become apparent that there are many benefits to the design solutions proposed. One of the most notable benefits of the design solutions became apparent in the cost-benefit analysis. The benefits of the design far outweigh the costs and subsequently resulted in a low payback period. The timesaving's possible are also a predominant positive aspect of the new proposed system. The new system estimates a time saving of approximately 6 minutes in total across the entire procedure and a much quicker start to evacuation in the crucial first few minutes of the evacuation. The proposed designs also include aids for those with an array of disabilities (mobility, cognitive, hearing and vision impairments). Finally, the designs add an extra level of control within the system, allowing for an increase in safety for residents. The client should use the analysis to inform future improvements in their fire evacuation system as well as investigating costs of installation and exact upfront costs to deem if they can fit within their budget for the coming year.

Appendix A – Survey Questions

How many years have you been a fire warden at the college?

- ○ 1
- ○ 2
- ○ 3+

Have you ever evacuated an area at the hall not in a fire drill situation?

- ○ No, I have only utilised the procedure in a drill scenario
- ○ Yes, I have evacuated the hall in a real evacuation scenario

What aspects of the procedure do you find EASIEST to complete

What aspects of the procedure do you find DIFFICULT to complete

What aspects of the procedure do you find TIME CONSUMING to complete

Please list any areas of improvement with the current fire evacuation procedure

Do you think the procedure would benefit from more fire wardens?

- ○ Yes, more fire wardens would be best
- ○ No, the current amount of fire wardens is adequate
- ○ No, less fire wardens would be best

Do you think the procedure would benefit from alerting the duty student when a fire occurs?

Currently the system does not alert anyone besides the sound of the alarm.

- ○ Yes, calling the duty student would be useful
- ○ No, there would be no benefit in calling the duty student
- ○ Might be useful.
- ○ Unsure if it would be useful.

Any thing else you would like to add?

Appendix B – Pairwise Comparison of Goals

Table B.1: Pairwise Comparison of Report Goals

	Disabled Support	Communication	Common Area Evacuation	Resident Response	**Score**
Disabled Support		0	0	0	**0**
Communication	1		1	1	**3**
Common Area Evacuation	1	0		0	**1**
Resident Response	1	0	1		**2**

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