TITLE:- OPERATIONS RESEARCH IN BUILDING EVACUATION PLANS.

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ABSTRACT

Evacuation modelling analysis is one of the most important and highly recommended research topics in today's world. It is of prime importance and concern for the safety of masses during emergencies. This paper focuses on how Operations research is being used in terms of evacuation modelling which is extremely important nowadays due to increasing complexity of buildings which raises the problem of evacuation. This is because of limiting conditions of fire smoke or any other kind of destruction and routes capacity. There needs to be one optimal evacuation strategy for a certain building which can get people out with minimum effort and time.

INTRODUCTION

BE PREPARED! BE AWARE! BE READY!

The time of an emergency is the most catastrophic and stressful time of a person's life. Everyday we hear several cases of fires, short circuits, attacks and emergencies taking place at various buildings and structures. A majority of people come out safe from these places because of the efficient evacuation systems installed in these buildings. These systems are effective because they have been developed after considerable research and application of various evacuation designing models. In this paper we will study how these plans are developed and how operations research helps in optimizing these plans and ensuring that 100% people come out safe from these emergencies.

Buildings must allow people to move freely at all times and evacuation should be as natural as possible. Instead of making an evacuation system and then make people, in the face of disaster, work according to the system , the system should be simulation based and should optimize the flow of people. This is generally for busy and large locations, even large festivals can use simulation based evacuation modeling. But this also poses a huge challenge since studying crowd behavior in a real disaster is very difficult because it puts people in a dangerous environment and every situation of emergency is different. (joao e almeida)

Evacuation of people in the event of disaster is one problem that has plagued human society since early ages. Evacuation modeling is essentially a combined approach for improving enclosure designs. This basically means to increase the preparedness in the face of a disaster. (joao e almeida)

This has existed for so long that, one of the seven wonders of world, the Temple of Artemis ,was built on a swamp , to protect it from constant earthquakes. But with time complexity of structure and infrastructure grew and the need for better measures came to light.

The first aim of these measures is to provide the occupants' safety in enclosed environment and avoiding and reducing the number of fatalities. (joao e almeida)

Approved document B (ADB) which provides guidance on meeting the requirements of the England and Wales building with regard to fire safety, specifies the width of exit routes such that the time required for the people inside to flow out of prescriptively designed enclosure, containing maximum design population is 150 seconds. However, the buildings with complex or innovative structures cannot follow traditional prescriptive design guidance and also its not available for more complex structures. (gyere)

The evacuation models, generally , might not consider the exit choice behavior, it means that people might not choose the nearest and the most optimal exit for the simple reason that the occupants might be unfamiliar with the layout of these buildings, especially in public buildings. They would most necessarily use the entrances and routes they came from, this results into congestion at main entry points. This is the reason that in order to ensure effective evacuation it is paramount to rely on trained staff.
Various models of operations will help in designing the most optimal and effective evacuation plans. (macdonald)

OVERVIEW OF THE INDUSTRY

Building evacuation is the process of making sure everyone inside the building gets out safely and in a timely and controlled manner on the happening of an emergency, such as fire. Buildings commonly use equipment such as fire alarms, exit signage, emergency lighting and emergency escape routes to conduct evacuations. (desigining buildings wiki)

In 1994, John Abrahams investigated building evacuation strategies and found out that the independent variables were the building's complexity and the mobility of the individuals. The strategy changes from 'fast egress' to 'slow egress' as the complexity increases and the mobility decreases. The end of this scale is the strategy of 'moving to a safe place inside the building' from where help can reach the individuals. In most buildings, these 'Safe Havens' will be in the stairwell, and in areas with a particular risk of earthquakes, buildings may incorporate them on each floor. (desigining buildings wiki)

Another form of evacuation is where building occupants react to the alarm and follow the directed means of escape to the place of safety away from the building. This may not be suitable for larger or more complex buildings due to the risks of congestion at escape routes. These buildings may be designed so that evacuation is initially limited to those nearest the hazard, before being extended to others. This type of phased evacuation strategy requires different alarm signals – a warning and an evacuation signal. (desigining buildings wiki)

Some countries like the US, Canada, Sweden, New Zealand, Australia and UK are in an advanced stage of development of these evacuation systems, they have developed and implemented performance based codes that are feasible and are instrumental in addressing the fire safety issues correctly. These performance-based codes have created a worldwide demand for computer evacuation models that will estimate time of evacuation for the buildings. In reality the development of such models became an important field of research and work within the Fire Safety Engineering (FSE) industry. For the last few decades, the evacuation models have been used to address fire safety issues within complex structures, where the prescriptive codes, mostly do not provide clear

guidance. Therefore, these models have been largely applied for estimating the RSET(Required Safe Egress Time), instead of the use of hand calculations. (R. MACHADO TAVARES)

All methods can be divided into 2 main classes:-

- EVACUATION PLANNING
- EMERGENCY MANAGEMENT

The global intelligent evacuation system market was valued at $504 million in 2016, and is projected to reach $775 million by 2023, growing at a CAGR of 6.7% from 2017-23. This market is expected to experience significant growth during the forecast period, owing to technological innovation in product offerings, rise in application areas among end users, and heavy venture capital investments in R&D activities to develop solutions with enhanced capabilities. (global intelligent evacuation system market analysis).

LITERATURE REVIEW

TITLE:- EMERGENCY EVACUATION MODEL AND ALGORITHM IN THE BUILDING WITH SEVERAL EXITS

The problems of evacuation with several exits under the limited conditions of fire smoke and routes capacity, an evacuation model combining of heuristic algorithm and network flow control has been established. Taking into consideration the routes capacity constraints, the aim of emergency evacuation is to minimize the total evacuation time for all people. The optimal evacuation path group, evacuation time and the number of evacuations in the evacuation network can be acquired through updating the evacuation network constantly and finding optimal routes iteratively. (chang liu, 2016)

The research on emergency evacuation has been carried out, and many scholars have adopted different methods to study the problem, which can be classified into mathematical analysis and computer simulation. Mathematical analysis method is based on the mathematical models, where the actual parameters of evacuation are converted into mathematical models to be solved, which can be further classified into macroscopic models and microscopic models. The microscopic models, such as cellular automaton model, multi lattice model and probability model, consider the evacuees individual characteristics and interactions in evacuation process. However, the selection of path evacuees in the evacuation area can't be solved easily, because the size of the building is huge. The macroscopic models ignore the individuals' behaviors in evacuation process and are based on network flow models, which can solve the problem of emergency evacuation. (chang liu, 2016)

Tjandra, proposed a single-source evacuation model which was a type of macroscopic model, to solve the routing problem. However, the capacity limit and priority of the path were also important to the choice of the evacuation path. Chen considered that evacuation routes could be calculated by Fast flow control algorithm, in order to get multiple optimal evacuation paths. Yang established a mathematical model based on the minimum time of evacuation by giving priority to the saturated shortest path. Additionally, some models have been reported on the optimization evacuation routes in case of fire smoke. Xie proposed a shortest path model based on the definition of equivalent length under concentration of fire smoke and crowd density. Yuan proposed that the evacuation speed of each arc in the evacuation network was expressed as a function of evacuation time and smoke diffusion, and built the optimal evacuation route algorithm. The optimal evacuation paths can be calculated by above evacuation models. (chang liu, 2016)

Some assumptions of the mathematical model:-

- It is a precautionary evacuation and all people to be evacuated obey the command by evacuation plan.

- There are multiple exits and only one source, capacity of every exit is limited.

- The capacity of every exit is transformed into an arc, and the capacities of other nodes are not limited.

- The speed of evacuees is not fixed among every arc in the evacuation network, and travel time among an arc is determined by the length of the arc and the speed of evacuees.

- The evacuation is required to preserve the FIFO (First-In-First-Out) property.

- Returning or cruising is not allowed.

Based on the network optimization method in Graph Theory, according to the objective function and constraint function in the mathematical model, the single-source-multi-exit evacuation heuristic algorithm is considered by influence of fire smoke and capacity of arcs to solve the NP (Nondeterministic Polynomial) problem. The shortest path to the exit was priority selected in execution process of this algorithm, and the capacity of path was fully utilized.

In this paper, the problems of the evacuation with several exits under limiting condition of fire smoke and routes capacity are studied, and an evacuation model is established by network flow control and heuristic algorithm. Minimizing the total evacuation time for all evacuees is the aim of evacuation model. The optimal evacuation path, evacuation time and the number of evacuees in each evacuation group can be calculated through updating the evacuation network constantly. (chang liu, 2016).

TITLE :- EVACUATION MODELLING ANALYSIS WITHIN THE OPERATIONAL RESEARCH CONTEXT: A COMBINED APPROACH FOR IMPROVING ENCLOSURE DESIGNS

Building evacuation is a systematic process and has to be done taking into consideration all the possible circumstances. Nevertheless, this task is challenging considering the actual growing complexity of the architectural designs, which introduces more fire risks. Evacuation and fire models have been developed to enable this process. In fact, the evacuation and fire models have been playing an important function in this process, since they help to assure that the solutions proposed by performance-based codes are feasible and are able to address fire safety issues correctly. This ''worldwide movement towards performance-based codes has created a demand for computer evacuation models that will provide an estimate of the evacuation time for a building''. (R. MACHADO TAVARES, 2008)

Recently everyone is shifting to performance based analysis and regulation. In other terms, it could be said that there are essentially two methods available for calculating evacuation times, the more traditional hand calculation approach and with the use of evacuation models. There are over 40 evacuation models. All of these models do have their advantages and disadvantages. But, in general terms, what makes them different from each other is the way they represent the geometry of the structure, the occupant's characteristics, etc. And besides that, the manner that their inherent algorithms work, will determine how accurate the evacuation model is. In the literature, there are some few evacuation models' reviews. (R. MACHADO TAVARES, 2008)

Evacuation process and safe design, what is the difference between them?

Evacuation process is simply the escape movement that people of an enclosed space make under emergency situations such as fires, earthquakes, flooding, etc.

Safe design is the design which could provide a successful evacuation process of the people in case of an emergency situation.

The mathematical equation for this can be put up as- RSET < ASET, where RSET means the Required Safe Egress Time; ASET means the Available Safe Egress Time. The pre-movement time is also known as pre-evacuation time. The difference between the ASET and the RSET is what the FSE community calls as the ''safety margin''. For a successful and safe evacuation the ASET should be greater compared to the RSET. (R. MACHADO TAVARES, 2008)

DEFINING SAFE DESIGNING PROCESS

The CFE (Computational Fire Engineering) models are used to estimate these two main timeliness: RSET and ASET. The evacuation models are used for estimating the RSET and the fire models, for estimating the ASET. To find out the clear picture a set of assumptions have to be taken into consideration like safety of the occupants.

EVACUATION TIME

Evacuation time is the index of the efficiency of the evacuation process. In other terms, the evacuation time is the variable used to measure the evacuation process' performance. Furthermore, this condition, in technical terms, should be the main objective of fire safety engineers when doing the evacuation analysis: to reduce the congested areas for improving the flow rate and consequently allowing the occupants to evacuate faster and safely.

Some summarizes the evacuation time as being a simple equation as follows: ET ¼ t1 þ t2, where ET is the evacuation time; t1 is the time to start the movement; t2 is the time to move and pass through the exits. (R. MACHADO TAVARES, 2008)

TITLE:- SIMULATION MODEL OF PEDESTRIAN EVACUATION IN HIGH-RISE BUILDING: CONSIDERING GROUP BEHAVIORS AND REAL TIME FIRE.

Introduction: In recent years the number of high rise buildings with complex structures have increased rapidly. Thus there is a growing need for improving the evacuation plans of these buildings in case of fires or other hazardous instances. (XUELING, 2015)

 THE FIRE EVACUATION MODEL:-

 1) Basic knowledge of cellular automata: Proposed by von neuman and ulam. States, neighbourhood and upstate rules are the three cores. Basic formula: S t+1= f(S t, N) in which s is a finite set of cells. N= (A 1,A 2,A 3,A n) (XUELING, 2015)

 2) Basic framework of fire evacuation: In high rise buildings the smoke spreads quickly. There are more number of people and thus makes it tougher for evacuation. Thus personnel evacuation model is a behaviour simulation model of a special group in a specific environment and specific places, under different fire development stage. (XUELING, 2015)

 3) The pedestrian evacuation group behaviour model: This model divides the area into grids. Each grid has walls obstacles and some of the grids have exits. These grids further have distinction between strong (young) and weak (children, old people) to prioritise the exit system. There has to be

an additional grid to determine in which direction everyone needs to move for efficient evacuation. (XUELING, 2015)

4) Real time fire environment model: Fire develops fast and its distribution is different. Fire behaviour determines people's behaviours and it influences their health. So we use FDS, a fire simulation software developed by USA. It analyses the smoke concentration, temperature, O2 C02. These simulation results are input into the evacuation model. The objective is to move towards the exits and avoid the obstacles. (XUELING, 2015)

Simulation experiment: Taking into account the CA mentioned, we construct a high rise building model. Grid partition rules are applied. Fire scenario and smoke levels are determined by FDS. The health and mobility status is evaluated. The number of people are 300. Reaction time on an average is assumed to be 20s. Taking all these things into consideration, the number of people evacuated when following the desired behaviour is around 10% more than those not following behaviour. (XUELING, 2015)

Conclusion: In the end I would like to conclude by addressing that fire evacuation is a complicated process. It depends on psychological and physical quality. There should be a cellular automata (CA) to research the group behaviour. FDS should be used to check the smoke components. With the use of full-fledged models fire evacuation can be carried out smoothly with minimal casualties (XUELING, 2015)

SIGNIFICANCE OF THE RESEARCH

The primary purpose of an evacuation plan is to provide for the safe and systematic evacuation of personnel and visitors in the event of an emergency. This plan comprises of certain procedures on how to report an emergency, what is the right thing to do, and who is available to assist you (shorenstein). This evacuation plan is designed very meticulously and a major role in its development is played by operations research.

When an emergency occurs at a workplace, there is a lot of confusion, and most people want to run and get out of the affected area or building as soon as possible, but doing so increases the possibility of injury and damage to property. The staff at the workplace requires a calm, level-headed set of leaders who are able to coordinate essential tasks and oversee an orderly evacuation.

Generally, a company needs four roles covered:-

•   POINT OF CONTACT:- this person communicates with the emergency services and makes the decision about when the evacuation should be performed.

•   COORDINATOR:- once the evacuation is declared, this coordinator completes the list of safety tasks, like shutting the gas lines, double checking the rooms in the premise and the bathrooms and securing the site as best as they can.

•   HEAD COUNTER:- on the outside of the building, these head counters ensure everyone is accounted for. If each department has a separate head counter, then all of them have to report to a central authority.

• FIRST AID:- the first aid kit will be very useful in treating minor injuries such as cuts and burns. Almost all members of the staff must have basic knowledge about the tools of the first aid kit. (eku online)

In the planning, control, and adaptation of evacuation plans, operations research models can make valuable contributions to support decision makers both in the preparation and the actual management of evacuations triggered by, natural disasters, terroristic threats, etc. For this reason, the development of evacuation plans is included as one of the primary research areas. (hamacher)

The study of operations research in building evacuation is very important for developing evacuation plans as it provides us with optimization models that help us in obtaining the safest and the fastest route to evacuate a building in the midst of an emergency. There are usually many exits to a building and in the time of a calamity a person can be confused about which exit is the best to escape. When operations research is used to plan evacuations, the escape is performed in a very efficient and systematic manner. Operations research throws light upon the various escape routes available and guides us into choosing the most .optimal and safe route out. The various models gives us the pros and cons of every route available and helps us in selecting the best and most effective route, which has the various advantages like easy and fast exit, more space for large number of people and a route with the most safety measures installed.

Our main objective is to throw light upon how operations research is used in the building evacuation industry and what is its importance.

METHODOLOGY

For this paper we have gone through and analysed 3 research papers and a few articles to understand how operations research is used in building evacuation plans. In these papers we got to study and see how various models are used to design evacuation plans. We have mentioned certain models which are popularly used in buildings. We have also analyses how high-rise buildings manage their safety measures. We have also mentioned the importance of research in this area and the significance of this industry. An example of a model used in a building is given for better understanding.

ANALYSIS

EVACUATION PLANNING

The main goal of evacuation planning is to reduce the number of casualties in case of hazards. There should be a proper plan and making sure that the occupants know what action should be taken in case of an emergency. A proper record needs to be maintained about the numbers of people who were safely evacuated and for those who were affected.

The first step to smooth evacuation is a well structured plan. It should take into consideration the risk attached. Identifying the potential hazards and risks both internal and external are vital for a proper plan. The probability of the occurrence of an event and it's impact should be prioritized . Evacuation are planned in stages. Some require evacuation of only a small area while other hazards require the entire building to be evacuated.

The steps involved in an evacuation planning procedure are-:

1)   Vulnerability assessment

• Historical- Chemical leak,fire,Weather situation, travelling obstruction

• Geographical- Floods, Cyclones, Gas leak, proximity to railways and airports

• Technical- Telecommunication failures, Computer failure, Power failure, Heating/cooling failure

• Human aspects – Poor training, fatigue, techniques, workplace violence, carelessness, misconduct, miscommunication

• Construction/design- evacuation routes, equipment and layout, physical construction, shelter areas

2) Analysis of the possible damages

• Chemical leak

• Smoke damage

• Water damage

• Communication line damag

• Building collapse

3) Impact assessment

• Impact on business

• Impact on property

• Impact on human life

4) Development of plans

• Security procedures

• Safety program

• Purchasing procedures

• Hazardous materials plan

• Fire protection plans

• Evacuation plans

5) Internal resources to prevent/control damage

• Sole source vendors

• Safety products

• Vital equipment staff

• Telecommunication

• Utility services

6) External resources

• Fire department

• Police department

• Government

• Public services

• Lepc

• Ems services

• Neighbouring businesses

These steps will help in ensuring minimal damage to life and property. Thus necessary precautions and procedures need to be followed. An immaculate plan is the key to successful evacuation of the occupants.
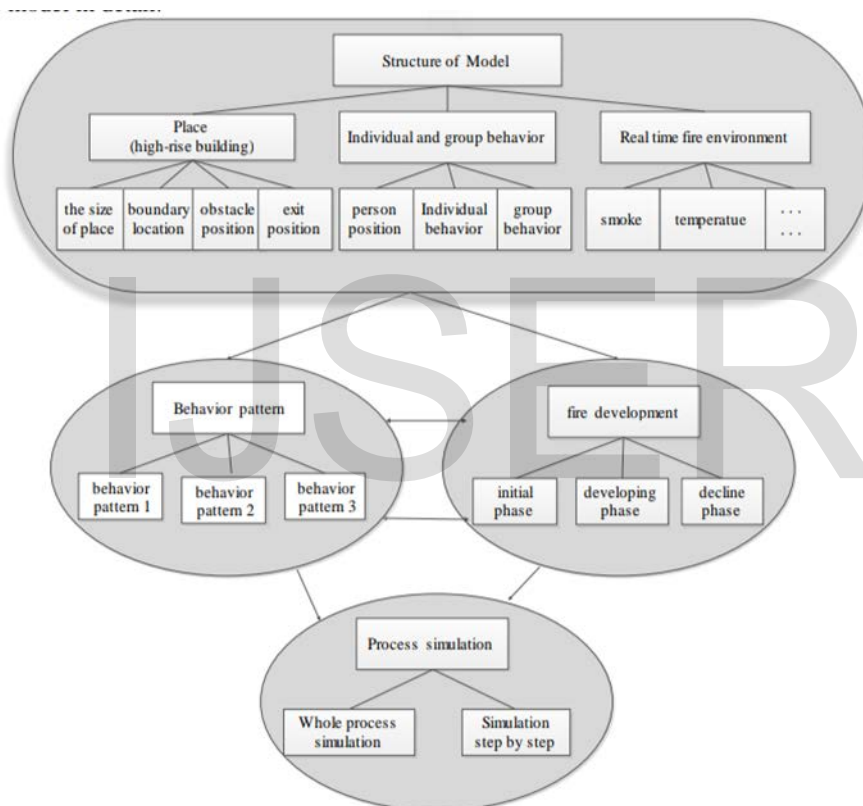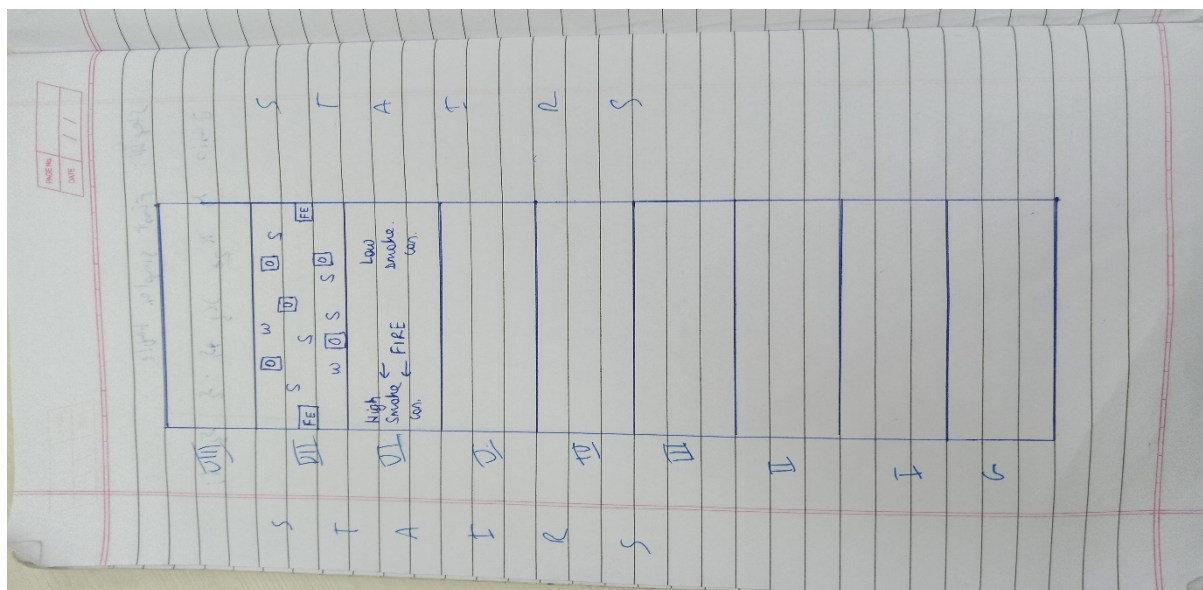
CONCLUSION

In this research paper we have done qualitative research on building evacuation. The evacuation process from Building can be shown in form of dynamic network-flow problems. We analyzed various network flow models that can be used to evaluate various variables. On using the tree network mode we found that it can be used for timely evacuation from buildings which have

convergent tree structure. Our research concluded that various linear and non-linear constraints can be used to fine time minimal routes for safety evacuation. The underlying network structure of a building evolves through time yielding a time-expanded network (a dynamic network). The objective functions used in such problem are more than one. If we evaluate, minimizing the total evacuation time and evacuating a portion of the building as early as possible are two such objectives. The research paper shows that network optimization is applicable in handling such multiple objectives. Minimizing the total evacuation time while avoiding cyclic movements in a building and "priority evacuation" are treated as min time flow problems. The vulnerability assessment proves to be useful as it gives solution to all the possible hazards that a building can probably face. In our research we found that internal resources to prevent and control damages are sole source vendors, safety products, vital equipment, telecommunication and utility services.

LIMITATIONS

- It was not possible to show the calculations of complex models.
- No primary data was obtained.
- It was not possible to develop an original evacuation model.

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