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# Executive Summary

# Research Paper

The world today is full of crowded streets and expanding businesses. Because of the need for space, many old buildings and structures are torn down to be replaced. The two major reasons leading to demolition of buildings are if it is condemned or a homeowner wants to redevelop it. Commonly in these old buildings there are a lot of hidden dangers for the workers assigned to bring them down. The old southeastern towns of the United States can be especially harmful, because of fragile architecture and hidden or covered up tunnels and basements. The focus of the BEST Robotics game this year is to teach and find innovative solutions to these demolition based problems and prioritize safety for these crews. The most common causes of these demolition accidents are structure failures, hazardous liquids and gases, and electricity paired with potential for fire and water. The priority of E.R.I.S. Robotics is to create a robot that faces these tasks and prevents them; solving them both efficiently and consistently.

To begin with, a leading danger of the crew’s work environment and prohibitor of their progress is previous or unknown architectural damage or failure. Architecture is not always reliable in the long run because the designer cannot know what might strike the building, whether it be storms or just material normal “wear and tear.” Even renowned British architect Norman Foster states, “As an architect, you design for the present, with an awareness of the past for a future which is essentially unknown” [1]. Designers try to use past experiences to influence the shape of their structure, however, what will eventually happen is impossible to predict. This creates dangers for demolition workers that hurt their progress, and slows down work time significantly because of consistent safety meetings that have to be held an upwards of 10-20 times per day.

To combat this, the first place the workers of Johnson, Bates, and Legg Construction would look is to find the original builder to see the weak points in structure. Unfortunately, the majority of the time there is no way to retrieve the original building plans. This leaves them with the process of examination which, at least for their company, has led to no fatalities so far. A system of documentation in a place like city hall or a local courthouse could easily solve this problem by devising a small department for keeping building records. Also, the coming presence and expansion of self automation in robots could allow for the workers to not only stay out of harm's way, but additionally, it would allow for quicker inspections because of the removed risk and safety factors.

Another potential form of severe damage in buildings is hazardous liquids and gases. The main form of this waste being found in old buildings is from hydraulic elevator fluid. This petroleum based solution has been predominant in elevators for over 60 years [2]. After years, the acid builds up under the elevator, leaving gallons of waste, and it has to slowly be drained, which is very time consuming. This also leaves a large window of time where the oil mist could be inhaled, which can cause damage to airways and lungs [3], and a worker who is exposed to it by touch experiences weakness in hands while any accidental ingestion of it can cause death [4]. With more common medical dangers, such as asbestos and mercury, the demolition site quickly becomes a very dangerous field of work.



Figure 1: Removal of Hazardous Waste

The technology to combat these problems was made possible by the HAZMAT (hazardous materials) suit. Modern civilian hazmat suits took development in 1940 [5]. This protective gear, created originally to defend U.S. soldiers in World War II, allows for safe excavation of this waste. Demolition crews also take time to make sure that every homeless person taking refuge there is out before they begin to tear it down. They have to take concern about other people being present and being exposed to these chemicals and fumes, and their job includes the guaranteed protection to move everyone out. Finally, the demolition crews also use any form of machinery whenever it is possible. They focus on putting the risk factor on the machine, rather than allowing more sources of damage to workers. Human lives are not replenishable, but machinery can be replaced.

Furthermore, demolition is delayed and hurt by potential for electrical problems, water damage, and future fires. The very first thing a demolition company does is to make sure that both the power and water are shut off completely, as told by Johnson, Bates, and Legg Construction. The property owner and the city both check to ensure that it is turned off, and ensure it in the form of a Demolition Certificate [6]. Even though this is certified by the city and the owner to be true, the demolition company still has to be safe and check for certain problems. For example, previous water leakage could cause walls or floors to be unsturdy and collapse. Also, a blown fuse, exposed wires, or waterlogged outlets or power boxes can lead to electrocution, and/or a potential to start a fire.

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Description automatically generatedFigure 2: Example Demolition Request Permit

Through careful inspection, many of these can be avoided, but sometimes it is impossible to see. This is why, going towards the future, using robots as scapegoats to take the falls is a breakthrough idea. Not only do they have the potential to save lives, but they also are expendable and could be built to work more efficiently than humans. Humans already rely on safety in using machinery to do tasks that would harm them physically, so controlling a robot, using what they have already been taught to do, would allow the job to be done safely. The challenge comes in designing a robot that could work more efficiently than normal, and that is what is being proved further into this Engineering Notebook.

To summarize, demolition is overall a risky form of industry. Over time, buildings wear down, hazardous material begins to take form, and electrical and water damages uncontrollably come and go. Technology has advanced to a degree to protect humans in their job, with both the HAZMAT suit and heavy machinery, but the dangers are still prominent. A replacement for humans would preserve the value of life, and going into the future, an efficient robot can ensure that. The speed at which demolition is completed and the environment for the workers can both be improved with the coming age of robots.

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# Implementation of the Engineering Design Process

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1. Ask (Formulating a basic idea based off of both goals and restrictions): The need of our robot is to better prepare and protect demolition crews from the destructive environment of damaged buildings. Currently, workers are putting their lives at risk with unknown problems lying beneath, above, and all around them. Our goal is to create a robot that can lower these risks and tear down buildings in a way that humans cannot; safely.
2. Imagine (Taking in opinions on how to solve a certain problem): By looking into the [\_\_\_research\_\_\_] we found \_\_\_\_\_\_\_\_. We then used this evidence and came together with a specific function in mind, which was \_\_\_\_\_\_\_.
3. Plan (Brainstorming how to put the ideas to use): Originally, we planned to use hooks to pick up various pieces of debris, pipes, and light posts, but we decided to rather use an arm and scoop for an easier autonomous experience and to move more debris at once respectively. We also used claws to grip the lampposts, and along with the spotter, could easily drop the lights into place with a single press of a button.
4. Create (Establishing the design in physical use): To create the robot we used a combination of a pvc frame with wood layer on top, cut out to have a scoop built into the robot, and we used our motors for two rear wheels that solely drive the robot (a two wheeled system) and for our arm, which is a dowel, that will pick up the pvc bundle.
5. Experiment (Trial and error of design to reach a certain standard): Our practice led to three main challenges. First, the autonomous function of the robot is to move into the pipe bundle, turn to the left 90°, and move the pipe bundle out of the zone, however, it ran into one of the lamp posts placed on the corner of the zone. Second, the function of the robot's arm was to extend the dowel and pick up the pvc bundle after moving it outside of the autonomous zone, but the pipe bundle kept slipping off. Finally, the light posts kept sliding out of the claws because they were not compressing around the pipes tight enough.
6. Improve (Redesign to reach a new achievement of function): To fix these problems, we redesigned our robot to fix: 1) the amount of time the robot moves forward and the degree it turns were both modified to avoid the base, 2) we put friction tape on the dowel to keep the pipe bundle from sliding off, and 3) we made the claws compress tighter to hold the poles.

# Brainstorming Approaches

Our first priority that drove the basis of the robot’s design is improving the safety of the demolition crew. By finding out how to fix these many construction/demolition site challenges in under three minutes, we can allow for some extent of real life reform to occur to increase safety overall for workers. We began by analyzing our requirements, including: putting up light poles, clearing and sorting debris, knocking down and cleaning up the resulting mess of a tower, setting up fences, and autonomously lifting a pvc pipe bundle and balancing it on a trailer. We focused the design of the robot to work by using our spotter and the ground of the playing field to its advantage. For example, we are planning to have our spotter load the light poles into the robot's three “claws,” so they will be carried at a certain height, just above the base of the lamppost, to be easily dropped into place. Additionally, we are taking advantage of using the general ground by sliding the debris with the robot, so we will not have to make use of a scoop that can easily get caught and/or fracture.

Furthermore, we inserted an autonomous command for the robot to move toward the pipe bundle and push it into a carved out gap, which has been made wide enough to have some marginal error and still work efficiently, and turn right 90 degrees to move out of the autonomous zone. We then will reposition the robot and use an extendable dowel with friction tape to pick up the pvc bundle, as to limit any chance of dropping the pipe bundle before reaching the trailer. In our team meeting, we also discussed the importance of balancing the pipe bundle on the back of the trailer instead of the front because of the weight distribution made possible by the placement of the trailer wheels. Our biggest and most heavily focused on agenda, however, was to make the robot easy for everyone to drive, no matter how much previous experience they may have had. To do this, we focused on limiting the number of buttons needed for commands, and even created two separate driving functions for people to decide which set of commands they found easier to use.

# Analytical Evaluation of Design Alternatives

Originally, we had two main ideas that ended up taking drastic turns. First, we had an idea to have a vertical, tube-like arm to pick up the whole tower at once and just set it in the debris pile to save on time. However, we abandoned the idea because of the height needed for it to originally extend over the tower, and since there were two base plates, it would be easy for the top slab to stop the compression system from properly picking up the bottom, resulting in more than one trip. We decided to instead just create a hollowed side of the robot by just cutting out part of it and surrounding it with walls to create a scooping mechanism. This way we could easily push the tower all at once without having to worry about second trips or crowded floor area to stop the robot. Second, we had specific buttons for the driver to press for a claw to close, so the spotter could easily load the lamppost. Though we soon realized an unseen problem; as seen in the rules and asked inside of the BEST forum, the driver is not allowed to touch the controller while the spotter is loading the lampposts. To combat this, we set a delay on the claw button commands, so the driver could set down the controller and allow the robot to autonomously grip the lampposts. Lastly, we also considered the driving conditions, and since there are many obstacles scattered throughout the field, including trees and the lamp bases, we decided to use small wheels on our robot. This would not slow us down, but it would allow us to have more precise movements with every touch of the joystick. Our goal is to focus on speed and consistency, and our ideas constantly develop towards that goal, reaching better heights with each new implementation and addition.

# Strategy Evaluations

## Offensive Evaluation

* The first goal of the team is to send the robot to get 520 points by autonomously moving to pick up the pipe bundle and lay them on the trailer for the balancing bonus. We will do this by running wooden dowels and prongs through them to pick up multiple instead of one at a time.
* The second task of the team is the hardest to accomplish. It is putting in the light poles for 225 points. We will have our spotter load the poles, and they will also assist the driver in lining up the robot to make sure the installment goes smoothly.
* We also will maintain speed by allowing the robot to knock over trees as long as they still remain in contact with their tape outline, so that they will still be counted as undisturbed.
* Next, we will set up the fences by reusing our prongs for 70 points, and we will attempt to obtain the Closed Polygon Fence Bonus.
* Lastly, we will pick up all the tower debris by knocking it into a scoop, and move everything we can into the dumpster without sorting for an estimated 300 points.

## Defensive Evaluation

* We used smaller wheels to have more precise commands, and cover less distance in a single left joystick press so as to not lose any time.
* We created the robot to be narrower to avoid knocking out poles or getting caught on trees, so that we would not disturb the set play field or tasks we had already completed and lose points.
* Server adapter to keep the 4-pronged claws lifted high enough above the carpet, so the wire prongs will not get caught on the loose strands of the carpet and stall the robot.
* We are also using pennies as counterweights to keep the whole back end of the robot dragging on the ground. This way, we can pick up a bigger amount of materials and the robot will not fall forward.
* Finally, we are using a two-drive system that also uses autonomous motion, and we are going to be able to give our team a few weeks of practice driving this fairly simple system before competition day.

# Software Development Process

# Safety

# Support Documentation