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Additive Manufacturing Design for Affordable Housing Development

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Additive Manufacturing Design for Affordable Housing Development
PROJECT CHARTER

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I. Purpose

Recently, there has been an increasing lack of affordable homes. Since rent, prices, gas, and other utilities continue to rise, wages (especially for low-income individuals) have stayed constant throughout the country. This has caused numerous citizens to not be able to afford a home or even pay rent. This situation has caused a large surge in the homeless community, and it is estimated that approximately 37,500 individuals per day are in need of housing throughout the Pacific Northwest as of January 2020. [1]

In response to this issue, our team has provided a goal to provide trendy and affordable homes for the homeless community. This will allow people to afford homes without having to break the bank. Our team will produce 3D-printing affordable housing that will help address the homeless community and integrate into a peaceful lifestyle and united community. We plan to present this project proposal for funding from the Seattle City Council which has a 2022 Housing Budget of $170 million, and the City of Portland which has at least $16 million allocated for new housing projects in 2022. [2, 3] We also plan to seek funding from other angel investors in the Pacific Northwest such as Portland Seed Fund, Cascade Seed Fund, Women's VC Fund II, Oregon Entrepreneurs Network, Alliance of Angels, and the Bill & Melinda Gates Foundation.

II. Objective

Our team will develop an additive manufacturing design solution for a prototype tiny home to meet customer needs, environmental considerations, economic constraints, and regulatory requirements. Our team will develop the prototype home design, and manufacturing will require externally developed additive manufacturing hardware and materials. This work will be the first subset of a larger project to print an affordable tiny home community in the Pacific Northwest. It is projected that the cost per home will be approximately an 85% reduction in cost, 60% reduction in waste, and 99% reduction in time from traditional construction methods. The use of additive manufacturing design technology will also enable improvements in design for sustainability, flexibility, and improved fire and seismic analysis. Projections on technology in the additive manufacturing space were based on details shared by other additive manufacturing companies in this space - including ICON, Mighty Buildings, and COBOD. [4, 5, 6] We expect to have our project completed in 69 weeks, with a budget of $1.4 million. This will be further explained in the schedule and resource sections.

III. Overview

The Additive Manufacturing Design project will consist of four main phases: 1) Human Centered Design, 2) Engineering Design, 3) Materials Development & Testing, and 4) Manufacturing & Integration. Our team will complete the design research, structural design, material testing, process optimization, and manufacturing for the project, and we intend to leverage partnerships for material sourcing and purchase of additive manufacturing hardware.

IV. Stakeholders

Our team's framework is a matrix organization. This will be led by the CEO, overseeing the Vice Presidents of each division, Vice President of Human Resources, and Project Director. Under the CEO, there are four main departments that will develop the additive manufacturing project. (Number of team members will be added). Our Project Director will be responsible for managing the key project phases: design engineering under the Engineering function, design research under the Brand & Marketing function, sourcing and testing under the Materials division, and manufacturing and integration under the Manufacturing division, as well as financial analysis under the Finance division. The VP of Engineering will lead the engineering division, with support from the Engineering Manager, Engineering Lead, & Engineering Team. This structure is the same for Brand & Marketing, Materials, Manufacturing, and Finance. The Vice President of Human Resources will work on their own. The Project Manager will be responsible for additional project details related to the Human Centered Design, Engineering Design, Materials Development & Testing, and Manufacturing & Integration phases.

The key external stakeholders on this project are the nonprofit organization and local government officials interested in providing housing for their community, any additional investors (not shown in appendices, but with similar interests and influence as the nonprofit organization), as well as the additive manufacturing hardware supplier, and materials supplier. A detailed description of duties and responsibilities, as well as matrices evaluating stakeholder support v. influence, and interest v. influence will be provided in Appendix B - Internal and External Stakeholders.

V. Schedule

The overall project schedule is 67 weeks, with 2 weeks of risk contingency schedule reserve. Tasks on the project's critical path are the following:

1. Engineering design research: permit requirements & printer specs.
2. Printer landscaping analysis.
3. Select partner printing company.
4. Install manufacturing & integration machinery.
5. Refine printing process parameters.
6. Print test parts.
7. Test sample parts
8. Material sourcing for prototype build.
9. Build the prototype tiny home.

Key project milestones include the following: 1) select printing hardware and material vendors, 2) meet sample part test specifications, and 3) complete a successful prototype tiny home build. A detailed breakdown of the project task schedule with associated effort hours estimation and slack time calculation, can be found in the Program Evaluation and Review Technique Chart in Appendix F, as well as the Activity Network Diagram in Appendix G. The project is expected to require 1809 total effort hours with 50% confidence, and 2460 total effort hours with 95% confidence. Therefore, we will account for a reserve of 651 total effort hours, as shown in the Probability Diagram in Appendix H.

VI. **Resources**

The overall project budget is $1,337,200, which accounts for the following items:

- Baseline budget: $1,187,200
- Management reserve: $150,000
- Labor cost: $266,400
- Material cost: $522,000
- Risk contingency budget: $310,000
- Risk contingency schedule budget: $88,800

A detailed breakdown of the project deliverables and associated material and labor costs can be found in the Time Phased Budget in Appendix L. The project is expected to incur a material cost of $522,000 with 50% confidence, $692,484 with 95% confidence. Therefore, we will account for a reserve of $170,484, as shown in the Probability Diagram in Appendix H. $400,000 of this material cost budget is allocated for the purchase and installation of the printer, and $40,000 is for prototype house materials and testing - as explained in the PERT chart in Appendix F. The labor cost is expected to be $266,400 - with employee hourly wage details provided in the Resource Load Table in Appendix K.

VII. Risk Management Plan

For our Risk Management Plan, our team has come up with five scenarios that could potentially disrupt our project plan. The five scenarios are:

1. Material Vendor Supply Delay
2. Test Part Failure
3. Integration Failure
4. Community & Government Design Rejection
5. Material Incompatibility

Risks 1 and 2 will be based on delivery and parts issues, while Risks 3, 4, and 5 will be based on design and material issues. We based the probability and cost impact of each risk based on common occurrences in real life. All the risks can cause a delay in the schedule impact of our project. The risk reserve was based on doubling the cost impact, to account for a threat that can occur anytime during the schedule. The response for risks 1 & 2 will be to determine backup materials and/or suppliers, expedite shipping, establish parallel design, fabrication, and testing for high-risk parts, or extend the timeline. The response for risks 3-5 will be to prepare a plan to contract and train manual labor, establish parallel design, fabrication, and testing for a second prototype iteration, establish parallel design, fabrication, and testing for an alternative material or printer, or extend the timeline. As mentioned, all risk responses will have to extend the timeline of the schedule. Reviewing and improving the project plan is an important and more effective risk management view than using standard risk management tools. The overview of the risk impacts is given in the table below:

	Risk Strategy	Budget Contingency	Schedule Contingency (weeks)
Risks 1- 2	Accept	$150,000	8
Risks 3- 5	Accept	$160,000	6
	Total	$310,000	14

Specific details of our risk management plan are provided in Appendix E – Risk Assessment.

VIII. Evaluation Method

The evaluation method of the additive manufacturing for affordable housing project will be monitored in various methods to ensure progression of the project, and to keep people accountable for deliverables throughout the project. The project manager is expected to keep everyone accountable for their deliverables to keep the project schedule on time. The CEO will have quarterly meetings in person with everyone who directly reports to him. The project director will host weekly meetings virtually and be available to emails and phone calls whenever necessary. The VP Finance will ensure that the project finances fall within the budget and will attend bi-monthly meetings in person and be available for email or phone calls and provide weekly expenditure reports that will be evaluated to the time phase budget using the 50-50 payment rule from Appendix L–Budget. Measuring the Cost Variance (CV), Cost Performance Index (CPI), Schedule Performance Index (SPI) and the Schedule Variance (SV) will be used to determine if the project is staying on schedule and within the given budget. This weekly analysis will be reported out to upper management and the CEO on a monthly basis. Estimated cost to complete (ETC), Estimated cost at complete (EAC), Variance at completion (BAC), schedule assessment will be included in the monthly report. While evaluating the various deadlines throughout the project is an important task to determine whether the project should be continued, the post project evaluation is also a key factor to preventing the same mistakes that occurred throughout the project the first time.

We will take action if the project exceeds or saves the amount of the management reserve of $150,000 which will be about 11% of the baseline budget. This means that the corrective action will be taken if the cost performance index (CPI) falls below 0.89 or rises above 1.11.

We will take action if the project exceeds 14 days of management reserve which is about 21% of the baseline schedule. Corrective action will take place if the schedule performance index (SPI) falls below 0.79 or rises above 1.21.

Refer to Appendix M – Control System for details and “Project Monitoring and Control Form” used to evaluate project status.

IX. Termination

The successful tiny 3D additive manufactured homes will be terminated by integration. Upon successful completion of the 3D additive manufactured home, the main committee will wrap up the documentation and eventually decide on whether or not to proceed with this prototype tiny home and whether or not it will be incorporated into the company's process to scale production. The project's equipment, personnel, and other infrastructure will be redistributed toward the company's future initiatives for the first tiny home community.

Steps to terminate the project are:

1. Finalize the prototype tiny home
2. Ensure the prototype tiny home meets quality and safety specifications
3. Host a tour with media and key stakeholders in the company
4. Form the project close-out committee: CEO, Project Director, VP Engineering, VP Materials, VP Manufacturing
5. Complete all tasks in the Project Termination Task List below
6. Provide, and securely store clear documentation of all sourcing, manufacturing, and integration notes for future reference

Refer to Appendix N – Termination for details and "Project Termination Task List Form" used to terminate the project.

X. Appendices

The appendices listed below are available in the attached Excel file.

A. Organizational Structure
B. External Stakeholder Analysis and Internal Team Personnel Requirements
C. Work Breakdown Structure (WBS)
D. Responsible Accountable Consult and Inform (RACI) Matrix
E. Risk Assessment
F. PERT Chart
G. Activity on Node (AON) Network Diagram
H. Probability Diagram
I. Baseline Schedule
J. Gantt Chart (Task & Summary Levels)
K. Resource Load Table
L. Time Phased Budget
M. Control System & Measures
N. Termination Plan

XI. References

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