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ACADEMIC RESEARCH PROPOSAL

RESEARCH METHODS & GIS (M5X01771, M5X01839 & M5X01904)

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List of Abbreviations

- I. United Kingdom: **UK**
- II. Living Wall System: **LWS**
- III. Living Wall: **LW**
- IV. Hydroponic Systems: **HS**
- V. Modular Natural Soil Systems: **MNSS**
- VI. Wire System: **WS**
- VII. Pocket or Pot Plant System: **PPPS**
- VIII. Building Information Modelling: **BIM**
- IX. Passive Heat Gain: **PHG**
- X. Urban Heat Island Effect: **UHIE**
- XI. Skyrise Greenery Incentive Scheme: **SGIS**
- XII. Carbon Dioxide: **CO2**



Proposed Implementation of Living Wall Systems on Domestic Buildings as a Cost-Effective Way to Prevent Localised Flooding and Reduce CO2 Levels in UK Cities.

1.0 Introduction

Currently, the UK's larger urban areas are struggling to deal drainage requirements and to meet CO2 emission targets. According to United Nations research, 66% of people will live in urban areas by 2050. (*World Urbanization Prospects, 2014*) The UK has a target of reducing its CO2 emissions to 80% below 1990 levels by 2050, as stated in the 2008 Climate Change Act. The current progression is indicating that this target will not be met. In addition, sewers are currently reaching maximum capacity with the amalgamation of increased rainwater and growing population.

For example, millions of tonnes of raw sewage and rainwater currently overflows into the Thames river every year due to its sewers reaching its maximum capacity. The 'London Tideway Super Sewer' project is a £5bn answer to London's sewage and rain water issues. It is to stretch 25km under the Thames to intercept, store and convey raw sewage and rain water to Beckton Treatment Works in East London.

1.0.1 What are Living Walls?

Living wall systems are designed to integrate directly into the fabric of the building to form the outer façade. Each module is pre-grown off-site and is installed using a clip system. A standard living wall (LW) comprises of cautiously selected amalgamation of plant species for that is suited for the area, creating a sustainable environment for urban wildlife whilst giving the area around the premise's fresh oxygen and less pollutants. The walls maintenance is straightforward, the system comes with a completely automated irrigation system and living wall expert teams can visit the owner regularly. To make the system even more sustainable, water used in the irrigation system can be harvested from rainwater that's landed on the properties roof through rainwater harvesting systems.

1.0.2 Research Aims

Living walls are implemented on very few buildings within the UK and when they do appear, they are found on innovative, flag ship, new build, commercial buildings. So, what if they were designed to be implemented onto domestic housing within the UK to help deal with drainage issues and emission standards? If they were standardised in the building regulations, would this make constructors less wary of them? Could government incentive drives for the systems further their development and increase their popularity? In addition, would the implementation of living walls in London principally be a cheaper and more sustainable alternative to the drainage improvement projects such as the £5bn London Tideway Super Sewer project?



1.1 Review of Literature

The implementation of vegetation into building facades has been suggested as a promising solution to make dense cities more sustainable. Characteristically, the vertical skin of buildings is larger than the roof area. This fact emphasizes that living wall systems (LWS) can be more beneficial than a living roof system (LRS). The concept of LW's dates to Babylonian civilization.

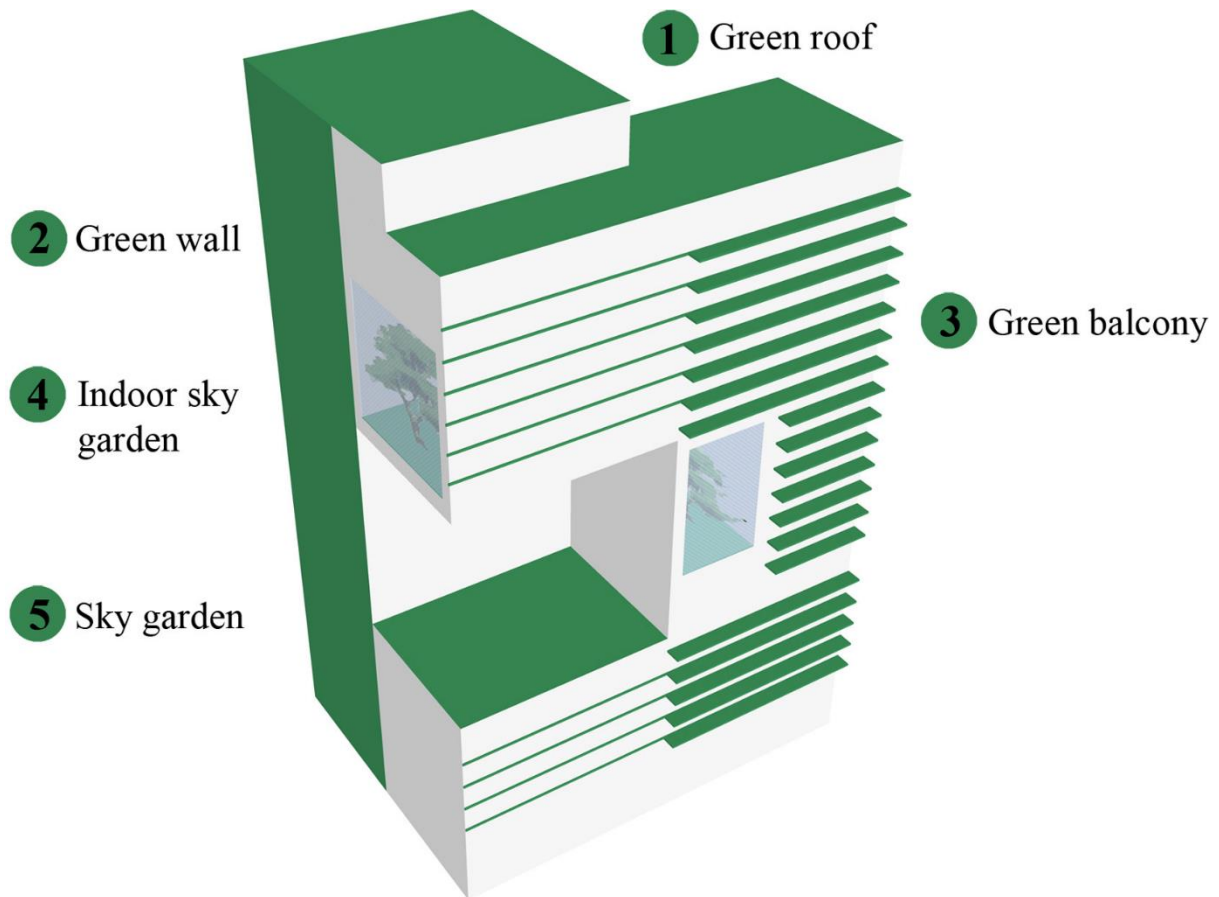


Figure 1: Green technologies that can be employed into the building fabric (**Roberto Giordano, 2017**)

1.1.1 Living Wall Systems

LW's have a complex structure including special supporting elements and an irrigation system to serve a large diversity of plants. Therefore, they are usually expensive and require high maintenance. However due to the modular structure of LW, plants can be pre-cultivated and then transferred to their place, these modules are commonly 600mm x 600mm in size. In case of damage or defect in one module, each section can be replaced easily.

There are 4 variations of LW systems;

- Hydroponic Systems (HS)
- Modular Natural Soil Systems (MNSS)
- Wire Systems (WS)
- Pocket or Pot Plant Systems (PPPS)



The system that would be most adaptable to retrofit domestic UK housing stock would be hydroponic system (HS) A typical HS living wall installation begins with softwood battens being attached to the existing external wall. This is trailed by a breathable membrane and fixing rails. The module, which has been pre-planted, will then attach to the rails. Pipework connected to the water (**see below**) is installed across the top of each module. The pipes incorporate pressure-compensated emitters for dispersing water. A water drainage network should be fitted at the base of the system.

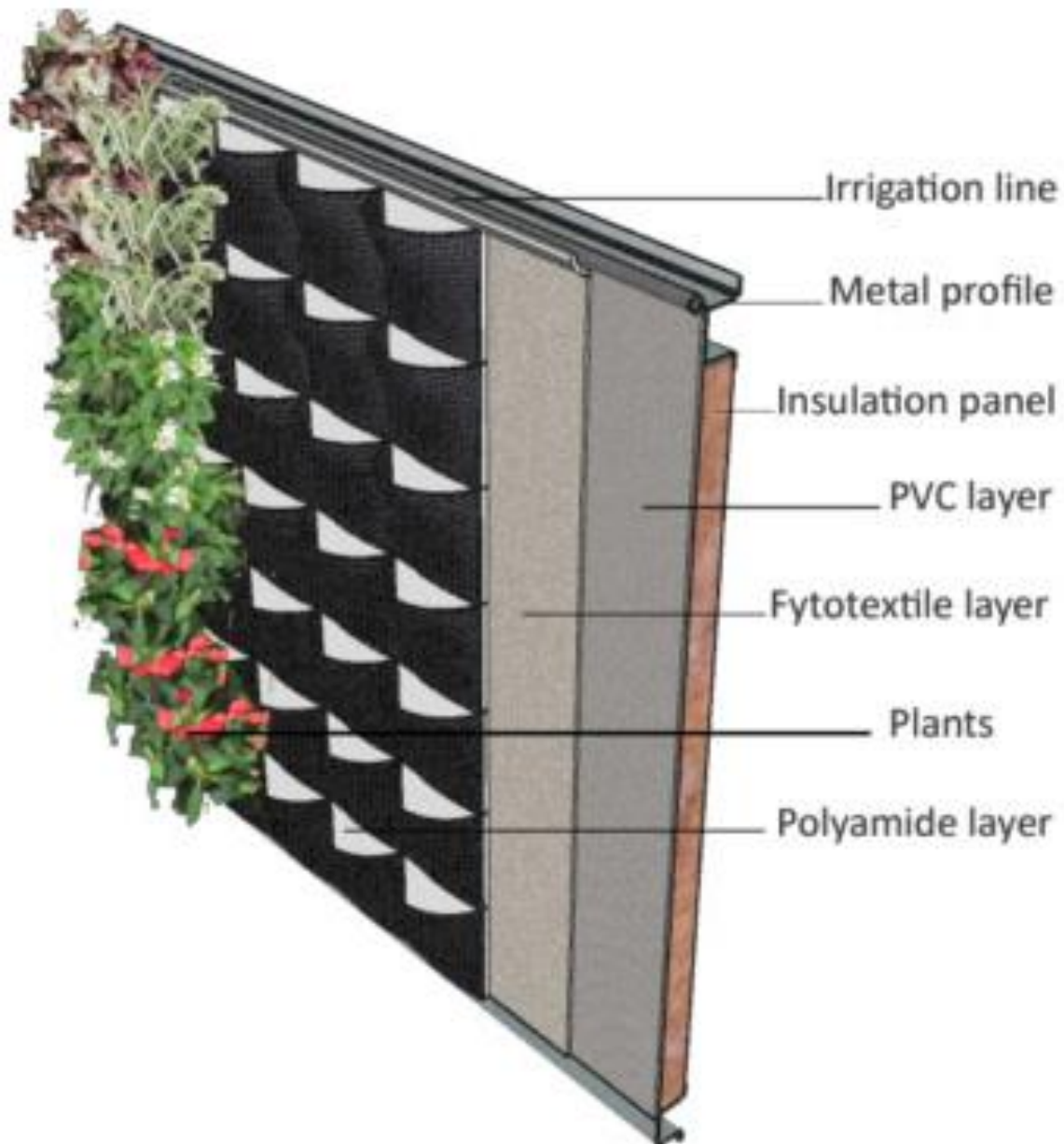


Figure 2: Visual representation of components in a hydroponic system (HS) (*Appleby, 2016*)

1.1.2 London Tideway Super Sewer Project

Currently millions of tonnes of raw sewage overflows into the Thames river every year due to the sewer reaching its maximum capacity. The population of London is currently 9 million which is predicted to reach 13 million in the next 30 years. Dozens of new apartment blocks and workplaces are being constructed every year and each must join up to the existing sewer network.

An increase in rainfall as a result of climate change puts extra strain on sewers across the UK. From 2000-2018 the United Kingdom's eight warmest and 4 out of its 5 wettest years had occurred. The 'London Tideway Super Sewer' project is a £5bn answer to London's sewage and rain water issues. It is to stretch 25km under the Thames to intercept, store and convey raw sewage and rain water to Beckton Treatment Works in East London.

1.1.3 Paper A

The technical standard proposal paper '**Living Wall Systems: A Technical Standard Proposal, (2015)**' is a main body of text that will be vital to taking the research proposal concept further. The paper recognizes LWS's as a strategic element for the design that offers many ecological benefits in the generation of sustainable cities and buildings. The paper highlights the importance of cities and local planning authorities encouraging architects to implement LWS's into their designs, but technical standards dealing with design, construction and maintenance of LWS's are rarely available.

The main purpose of the paper is to inspire the LWS's development by providing their own technical standard proposal with information, and specifications. It tackles some aspects that should be considered significant in a standard such as: design guidelines; maintenance procedures; requirements and indicators for assessing the expected performances.

The technical standard proposal suggests that it is advisable to employ a structural engineer for any LW project. Whatever the desired effect, the use of building information modelling (BIM) can help to ensure a successful completed LW project. The LWS should be considered at an early stage of a building's design, so that precise allowances can be made for its implementation.

1.1.4 Paper B

The literature review '**The Impact of Greening Systems on Building Energy Performance: A Literature Review (2015)**' is another main body of text that will be referenced to answer my research questions. It assesses the effect of living wall systems on the energy efficiency of buildings and other benefits. The literature review highlights the following;

LW's contribute efficiently in reducing the internal temperature of structures by absorbing the solar radiation from the sun for growth and biological processes. A reduction of indoor air temperature subsequently results in a considerable energy-savings for air-conditioning during summer periods. However, the paper highlights the issue that the shading by plants should be designed not obstruct the passive heat gain (PHG) during winter times otherwise this will increase the heating requirement.

LW's are made up of plants that can help absorb pollutants from the air. In fact, one facade can contain thousands of plants that can filter air as well as create energy-rich oxygen. From an acoustic perspective, LWS can extensively help to reduce noise internal because the leaves of



the plants reflect and absorb acoustic energy. Externally, this helps reduce the effects of city noise while internally, reverberation can be significantly reduced.

LW's encompass a carefully designated combination of plant species for the area, generating a sustainable environment for numerous creatures; and importantly, critically essential extra habitat for UK urban wildlife.

Greenery system						
Energy impact		GR	GW	GB	SG	ISG
Summer cooling	Evapotran spiration ↑	[+] Leaf area index [+] Substrate moisture content	[+] Leaf area index [+] Substrate moisture content	[+] Leaf area index ****		[+] Leaf size [+] Irrigation
	Shading ↑	[+] Coverage ratio [+] Foliage size [+] leaf angle distribution (Horiz)*	[+] Coverage ratio [+] Leaf area index [+] Using LW system with planter boxes	[+] Shading coverage [+] Shading density [-] Wall-vegetation distance [+] tree height [+] Shading on west side		[N/A]
Winter heating	Evapotran spiration ↓	[-] Substrate moisture content**	[-] Substrate moisture content	[-] Substrate moisture content *****		[N/A]
	Shading ↓	[-] Shading coefficient (deciduous plants)	[-] Shading coefficient (deciduous plants)	[-] Shading on south and east sides		[N/A]
	Insulation ↑	[+] Substrate thickness [-] Substrate moisture content*** [+] Plant diversity [-] Substrate density	[-] Wall-vegetation distance	[+] high coverage in the direction of cold winter wind [-] Substrate moisture content		[N/A]
↑ The effect should improve; ↓ The effect should decrease; [+] Higher value or quantity is needed; [-] Lower value or quantity is needed GR: Green roof, GW: Green wall, GB: Green balcony, SG: Sky garden, ISG: Indoor sky garden						

Figure 3: The impact of greenery concepts on building energy consumption (**Babak Raji, 2015**)

From an aesthetic perspective, LWS's can conceal visual blemishes and enhance any public space rendering them more aesthetically pleasing. They can also help to shield exterior walls from weather damage and corrosion.

1.1.5 Paper C

The technical report '**Living Roofs and Walls Technical Report: Supporting London Plan Policy (2008)**' is the most recent LWS publication issued by the Greater London Authority and is



therefore what can only be referenced when discussing London's adaptation of LWS. Other documents such as the '**Urban Greening Factor for London Final Report (2017)**' and the '**London Regional Flood Risk Appraisal First Review (2014)**' will support this main body of text and my research proposal.

The Living Roofs and Walls Technical Report assesses London's potential to adapt LWS to combat cumulative risks of localised flooding, overheating and drought, through hotter, drier summers and warmer wetter winters. The report predicts that *"Summers by 2050 will be 1.5-3.5°C hotter, in central London the urban heat island (UHIE) currently adds 5-6°C to summer night time temperatures and will intensify in the future"*

"An Urban Heat Island is a metropolitan area which is significantly warmer than its surroundings. As population centres grow, they tend to have a corresponding increase in average temperature. Not to be confused with global warming, scientists refer to this phenomenon as the "Urban Heat Island Effect" (Urban Heat Island Effect ("UHIE"), 2004) UHIE is a big problem in London and through the research obtained it is shown that LWS are known to reduce this.

It also supports other research problems at hand, in that LWS are not appropriately adaptable due to the following barriers;

- Lack of a national and local policy framework that encourages the installation of living roofs and walls,
- Lack of expertise and services,
- Lack of a common standards
- Maintenance,
- Cost effectiveness,
- Fire hazard,
- Structural weight issues,
- Leakage and resultant damage to waterproofing and exterior wall.

The then Mayor of London's' chief advisor on architecture and urbanism, Richard Rogers, once specified that - "A requirement for living walls and roofs to be part of all major development that would deliver a step change in the battle against climate change and the delivery of a more liveable city."

1.1.6 International Adaptation

- In Germany the use of a LWS's is judged to provide a defensive barrier for structures, preventing waterproofing elements from catching fire. It is for this reason, it is possible for building owners to get a discount of between 10%-20% on their fire insurance.
- Singapore in 2009 launched the "Skyrise Greenery Incentive Scheme" (SGIS). The scheme finances up to 50% (or 500\$ per square meter) of the installation cost of LWS's on existing and new buildings.

1.2 Methodology

To answer the given research question, a combination of quantitative and qualitative research methods would be required. The qualitative research conducted will be through interviews, interviewees will include;

- Built Environment Students



- Environmental Conservation Students
- Senior University Lecturers
- Home and Business Owners
- Living Wall Industry Experts

These interviews can be recorded face to face or through utilising social media applications such as Skype and Facebook. E-mail communications methods of contact would also be employed. From the qualitative research it is expected that the understanding of underlying reasons, opinions, and motivations behind the need for living walls are produced.

Quantitatively, a survey ought to be conducted on home owners in London to assess the attitudes towards living walls and the likelihood of them adopting one. In addition, further parameters such as property value and the hypothetical prospect of government incentives will be questioned to see if their decision is influenced. It is also hoped that from the quantitative research uncovers trends in people's attitudes which will help dive deeper into the prospect of adaptation onto existing buildings within London. To conduct this survey, the online application 'survey monkey' should be utilised as it allows the user to reach the right target audience. Meaning the London based home-owner demographic can be reached.

By using the two different types of research it also will allow for the study to be more diverse and look at differing attitudes towards living walls, which will result in having a better understanding of the prospect.

1.2.1 Research Project Plan

Research Proposal Project Planner

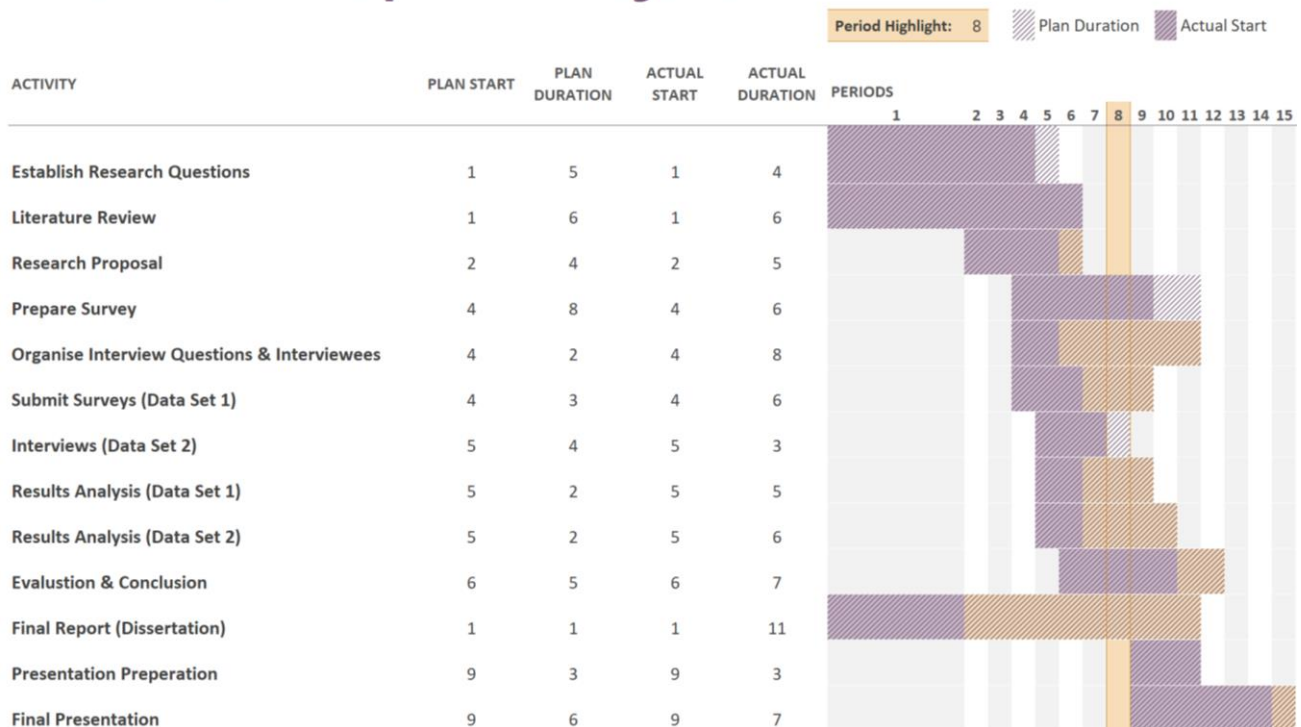


Figure 4: Research Proposal Project Planner (1 'Period' = 1 Week)



1.3 Results

All raw data results obtained through the survey (*see appendix 1*) and interviews should be recorded into tables and then transferred into bar chart and other graphical forms. It is from these visual representations that the following can be analysed;

- Positive correlation.

For example, it is expected that from the survey there will be a positive correlation between those living in urban areas and those who believe that all future government-built buildings have compulsory 'living wall' systems installed. Where those seeing the effects of localised flooding and CO2 pollution in the city centre will have stronger attitudes towards combating climate change.

- Negative Correlation

It would be expected that the surveyed would be living in a house that is pre-1980 in construction as 75% of houses in the UK were constructed before then. In addition to this, I expect that a negative correlation between the properties age and the likely hood of living wall implementation will be evident. The newer the property, the less likely to adopt.

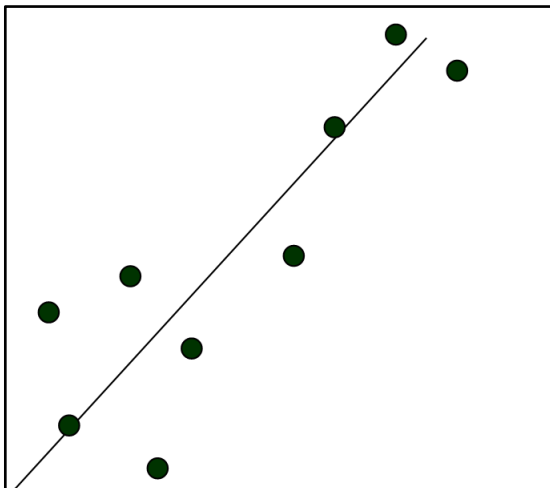


Figure 5: Positive+ Correlation

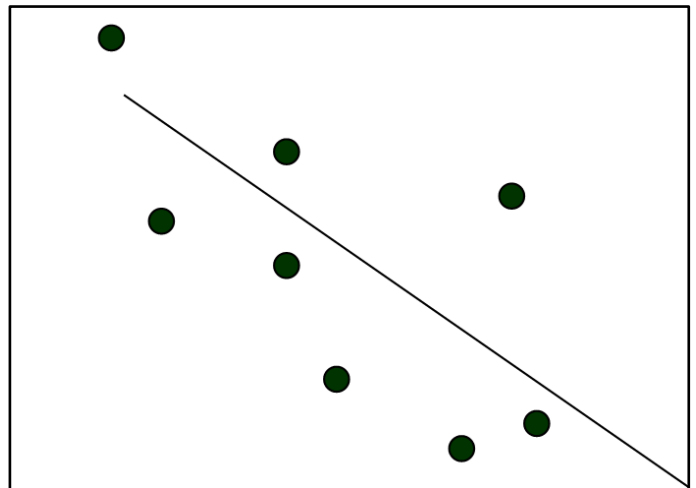


Figure 6: Negative- Correlation

- Regression

“Regression studies are excellent tools when you need to make predictions and forecast future trends. Regressions measure the relationship between a dependent variable (what you want to measure) and an independent variable (the data you use to predict the dependent variable)”
(SISENSE, 2017)

- Hypothesis Testing

This analysis technique lets the researcher compare the data obtained in the hypotheses and assumptions made about the operations against what discoveries have been made. It also helps the researcher forecast how decisions could affect data organization. For example, the researcher hypothesises that those living in central London would be more likely to adopt a living

wall where as those at a 30km radius from the city centre near the M25 in the Surrey Hills Area of Outstanding Natural Beauty and Windsor will see the effects of flooding and CO2 pollution less so will see less need for adaptation. This hypothesis would then be compared against the fresh data from the survey.

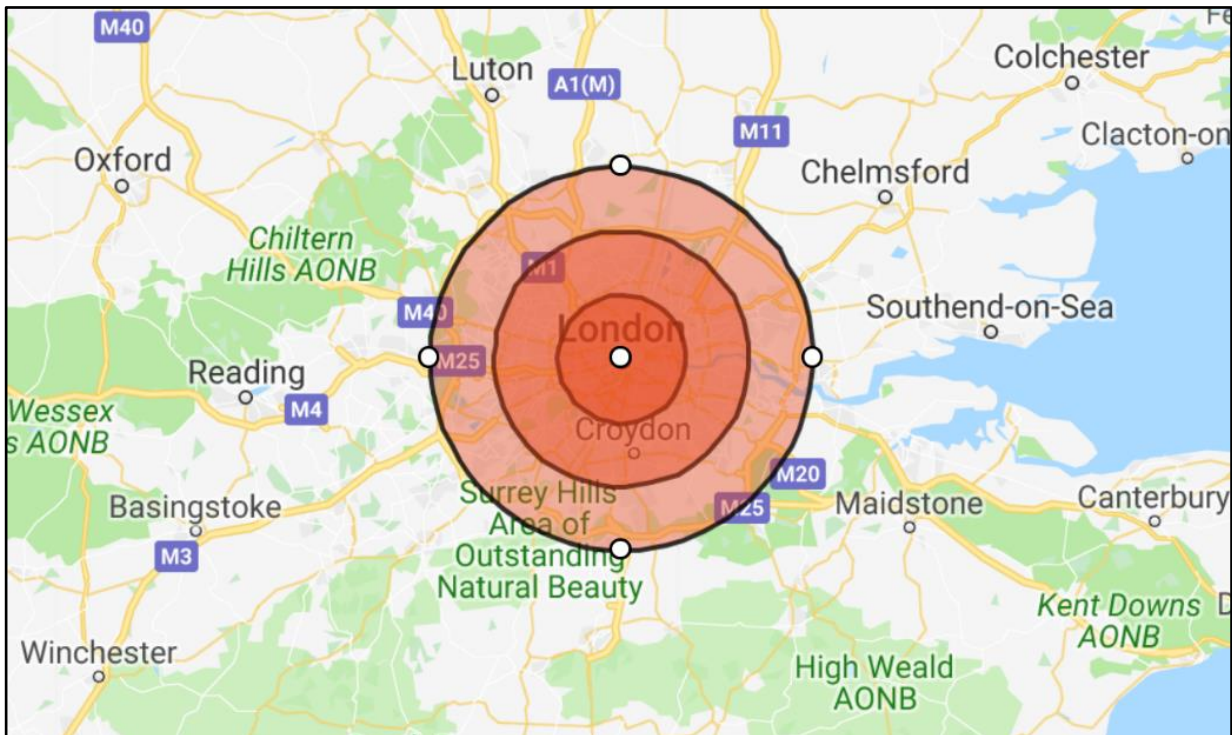


Figure 7: 10km, 20km and 30km radius of Central London (*mapdevelopers, 2019*)

1.4 Evaluation

If standardised building regulations could incorporate LWS's then constructor' adaptation should increase. As a result, their implementation into existing domestic housing within the UK will help deal with drainage issues and emission standards. Government incentives could help this movement and in turn improve constructor's skillset and take off new businesses as a result. There is potential for LWS's to deal with drainage issues at the rainwater source which would eradicate the future need for expanding existing sewer systems; such as that currently being constructed in London.

The main limitations of this research are financial, geographical and knowledge based. Grants and other funding would be necessary to recruit researchers and to hire the relevant facilities and test equipment. Also, the knowledge in this field is lacklustre, meaning the researcher will need to search further afield for expertise and assistance. In addition to this, the case study of the London Super Sewer will be limited to desktop investigation and electronic surveys of the London resident demographic as the researcher is based in South Wales.

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Appendices

Appendix 1: Living wall survey proposal

Living Wall Systems

Instructor: Adam Meyrick

Name: _____

Institution: University of Wales Trinity Saint
David (UWTSD)

Date: _____

This questionnaire aims to educate the public of what living wall systems are and aims to assess the feeling towards their implementation on domestic housing.



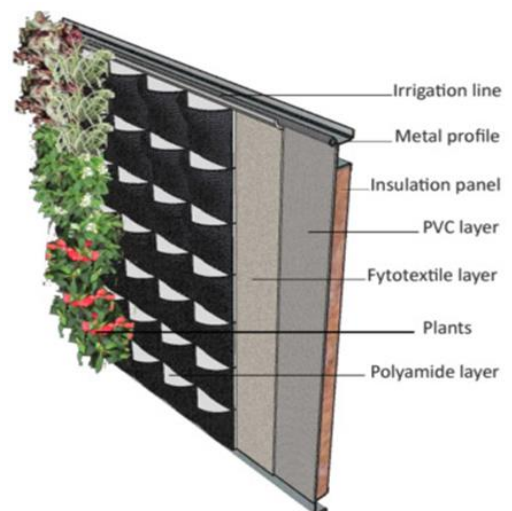
(Figure A1; New green wall system launched (17 October 2016, by Matthew Appleby)

The walls maintenance is straightforward, the modular system emanates with a fully automatic irrigation system and living wall expert teams can call-by recurrently.

To make the system even more sustainable, water used in the irrigation system can be harvested from rainwater that's landed on the properties roof through rainwater harvesting systems. Living walls are implemented on very few buildings within the UK and when they do appear, they are found on large, new build, commercial buildings. What if they were implemented on existing domestic housing within the UK?

Living walls are designed to integrate directly into the fabric of the building to form the outer façade. Each module is pre-grown off-site and is installed using a clip system. **(See figure a2)**

A guideline LWS encompasses a careful combination of plant classes that is suited for the area, creating a sustainable environment for urban wildlife whilst giving the area around the premise's fresh oxygen and less pollutants.



(Figure A2; Fabric living wall system (Scotscape, 2014)

Please tick and circle the answer(s) most relevant to you.

1. Are you a home owner?

- a. Yes
- b. No

2. What area code do you live in? (e.g. SA1, SW18, SA4)

3. When was your house built?

- a. 2000 - Present
- b. 1970 - 2000
- c. 1945 – 1970
- d. 1920 – 1945
- e. 1901 – 1920
- f. Older

4. What is your approximate house value? (Optional)

- a. Over £250,000
- b. £200,000 - £249,999
- c. £150,000 - £199,999
- d. £100,000 - £149,999
- e. £50,000 – £99,999

5. What would be a reasonable price for a system to be implemented onto the front of a typical domestic house?

- a. More than £5,000
- b. £4,000
- c. £3,000
- d. £2,000
- e. £1,000



6. What type of property do you live in?

- a. Detached
- b. Semi-detached
- c. Terraced
- d. Apartment

7. Should there be a government incentive to adopt a living wall on our homes?

Strongly disagree				Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

8. Do you believe they are aesthetically pleasing? (*See Figure: A1*)

- a. Yes
- b. No
- c. Not Sure

9. Do you believe they will help the environment?

- a. Yes
- b. No
- c. Not Sure

10. Do you agree that all future government-built buildings (e.g. hospitals, schools) should have compulsory 'living wall' systems installed? (Where applicable)

Strongly disagree				Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

11. Do you think 'living wall' systems help improve energy efficiency in buildings?

- a. Yes
- b. No
- c. Not Sure



12. Do you think 'living wall' systems help improve noise reduction in buildings?

- a. Yes
- b. No
- c. Not Sure

13. Would you adopt a 'living wall' system onto your property?

- a. Yes
- b. No
- c. Not Sure

14. If yes, where would you most likely like to implement one?

- a. Front
- b. Back
- c. Gable End

15. Do you think a 'living wall' would improve the value of your property?

- a. Yes
- b. No
- c. Not Sure

16. What concerns do you have with living wall systems given your brief introduction to the concept?

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