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A field GIS solution to Derelict Sites and Dangerous Structures Management

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Key words: Derelict Sites, Dangerous Structures, GIS, Multicriteria Decision Analysis

SUMMARY

The subjective nature of the definitions and lack of guidance under the Derelict Sites Act 1990 and the Local Government Sanitary Services Act 1964 (Ireland) have led to inconsistent applications of the Acts and a reluctance to enforce. Dereliction has been a blight on the scenic beauty and attractiveness of town and countryside in Ireland, taking away from their appeal to inhabitants, investors and tourists. The Derelict Sites Act 1990 was introduced to empower local authorities in the remediation of problem sites. Part 8 of the Act requires that Local Authorities keep a register of derelict sites. The register is used to apply a levy on lands and to encourage owners to remediate sites. Part 10 of the Act requires that Local Authorities take reasonable measures to ensure that sites in their functional area does not become or continue to be Derelict.

Dangerous structures pose a problem to local authorities and many sites initially start out as Derelict Sites become dangerous over time posing a risk to property and persons. Local Authorities are liable for the safety of public areas and steps must be taken to ensure that they are made safe promptly. A recent amalgamation of North and South Tipperary County Councils have highlighted problems with the reporting and recording of Derelict Sites and Dangerous Structures due to problems interpreting the definition of what is derelict and what is dangerous when sites are assessed by different professionals.

The lack of uniform standards for site assessment can lead to problems with the management of sites, they are difficult to compare and rank for prioritising sites for future action and remediation. Comprehensive research into the area of dereliction and dangerous structures was undertaken and set of criteria produced to identify what is 'Derelict' and what is 'Dangerous' based on a critical combination of site indicators, group decisions and geographical data.

It is possible to quantify dereliction and danger by using a web and smartphone application and Feature Manipulation Engine (FME) software. The generation of standardized sites scores from the data input using the smartphone app combined with weighted thematic maps in a GIS environment allow problem sites to be ranked in order of priority for remediation works. A GIS-based web application offers an effective solution to the above problem by removing the subjectivity from the definition of derelict sites and dangerous structures.

1. INTRODUCTION

In 2014, a government Putting People First rationalisation programme aimed at improving the effectiveness of local authorities in Ireland, resulted in the amalgamation of North and South Tipperary County Councils While this Government initiative was well received, it did present many challenges for the newly formed Tipperary County Council.

Following the merger prioritising work on Derelict Sites and Dangerous Structures was challenging, owing to the different ways report and assessments of these had been carried out by both local authorities. In addition, reporting on Derelict Sites and Dangerous Structures is undertaken by many professions, including Architects, Engineers, Planners and Technicians and has further resulted in no uniform standards being adopted by local authorities.

The interpretation of the term Derelict and Dangerous varies depending on the professional background of the personnel collecting and recording this information in the field. For example, an architect may view a derelict structure differently to an engineer. Interpretation of what is derelict can be very subjective based on their own opinions and experiences.

After the amalgamation, Tipperary county was divided into five municipal districts, each having a technical officer assigned to reporting on derelict sites and dangerous structures. As the legislation does not formally define dereliction, a new set of criteria was established to determine dereliction and to determine what is an amenity, so that each district is enforced equally. This will aid local authorities in ensuring that their obligations and duties under the legislation are met in all municipal districts.

This paper focuses on the issues experienced and proposed solutions for a standard method of assessing Derelict Sites and Dangerous Structures and the generation of a site scoring system using multi criteria decision making within the newly formed county council that could be used by local authorities nationally.

To overcome these problems the following three-stage solution for the management of sites is proposed:

- Build a web and smartphone application to collect derelict and dangerous site data.
- Determine the level of site dereliction based on indicators collected from the web and smartphone application.
- Use geographic data in conjunction with site scores to determine the level of impact on amenities within a neighbourhood.

A web and smartphone application was built using ESRI's SURVEY 123 platform and was designed to assist site investigators in making a standard and uniform assessment of sites based on an onsite checklist . Data input into the app is in a logical order and consists of a series of questions relating to the structural elements of the building. Questions are in a Yes/No format, and where relevant a quantity is recorded, together with relevant photography. Site dereliction is determined by various indicators such as rubbish, peeling paint, dirty facades, broken windows and holes in the roof for example, which may affect the level of impact the building or site has on the amenities of the neighbourhood or threat to public safety. The overall condition of the surrounding land is then assessed for litter, dumping graffiti and other undesirable and unsightly items and also recorded. The location of the site is logged, using the smartphone's GPS sensor and background map.

Once collected the data is uploaded to ESRI's ArcGIS online database. Following the data collection mathematical operations are performed on the data using Feature Manipulation Software (FME) to output site scores based on the impact sites have on surrounding amenities thus allowing for prioritisation of sites based on the output scores. Standard reports are generated, and the sites are plotted on a webmap for viewing and analysis.

1.1 Literature review

Multi criteria Decision Making (MCDM) has been applied in the area of derelict and mismanaged sites (Antucheviciene and Zavadskas 2008; Zavadskas and Antucheviciene 2006, 2007). Antucheviciene argues for the use of MCDM in the prioritisation of sites for sustainable redevelopment of Derelict and underused former soviet rural agricultural buildings in Lithuania. Buildings are prioritised based on their state of repair, environmental performance, territorial distribution and compliance with sustainable development, Sustainability indicators from a variety of standards are used in the decision-making model. A technique for order performance by similarity to the ideal solution (TOPSIS) is used.

(Myers & Wyatt 2004, Chang; Parvathinathan and Breeden 2008) make a case for the use of group expert decision making, combined with GIS to screen suitable areas for landfill development. The authors propose a method of including the opinions of experts where there is lack of crisp information, in relation to criteria that are not easily quantified. A two-stage process is proposed for identifying sites, the first using thematic maps and raster overlays of available data and a second stage analysis using Fuzzy Multi Criteria Decision Making (FMCDM).

The disparities in judgement between experts can be minimised by the inclusion of more experts. Expert decision making is added to a decision matrix using linguistic quantifiers and fuzzy numbers. An assumed weighting set w = (Very Poor, Poor, Fair, Good and Very Good) is applied using fuzzy numbers (Zadeh 1965). Ambiguities in the importance of each criterion can be dealt with quantitatively by the translation of verbal expressions into numerical ones using a fuzzy linguistic model. Planners and field experts were invited to participate in the decision-making process by means of a questionnaire. The study differed from other studies by proposing to integrate MCMD with a two-stage process rather than a fully integrated arrangement.

Akbari et al. (2008) and Charnpratheep, Zhou & Garner (1997) offer a similar arrangement with group decision making by experts in relation to landfill modelling, GIS is used to screen unsuitable areas. For the first stage geographical criteria analysis, land is classified using raster maps and an even grid size spacing. Buffers are placed laterally along routes and unsuitable land parcels are eradicated. (Pasi and Yager 2006) use the concept of Induced Ordered Weighting Averages (IOWA) to synthesise an overall majority by aggregating individual opinions into an overall value.

Majority opinions are modelled using fuzzy logic and linguistic quantifiers. (Boroushaki and Malczewski 2010) use a fuzzy majority approach that combines criterion mapping using weighting applied by experts and aggregates mapping to collective choice and create a tool in an ArcGIS environment.

Professionals such as Architects and Engineers may have differing opinions when rating streetscapes. Studies by (Weich et al. 2001; Weich 2002) have shown that it is possible to come up with a solution to objectively rate streetscapes from a visual and architectural point of view. Objective evaluations of the built environment have been carried out using a Built Environment Survey checklist, developed by Weich, an Architect. Streetscapes and housing were evaluated using 27 criteria to rate the characteristics of a neighbourhood.

While the techniques of Multicriteria decision making and group expert decision making have been used in the past for site selection and ranking, the current research applies these to the area of determining site dereliction and provides a GIS and smartphone-based solution for calculating standardized site scores of site dereliction.

1.2 Problems with the definition of Derelict

The Derelict Sites Act 1990 (Ireland) defines a Derelict Site as:

> any land which detracts, or is likely to detract, to a material degree from the amenity, character or appearance of land in the neighbourhood of the land in question because of—
>
> (a) the existence on the land in question of structures which are in a ruinous, derelict or dangerous condition, or
>
> (b) the neglected, unsightly or objectionable condition of the land or any structures on the land in question, or
>
> (c) the presence, deposit or collection on the land in question of any litter, rubbish, debris or waste, except where the presence, deposit or collection of such litter, rubbish, debris or waste results from the exercise of a right conferred by statute or by common law

The interpretation of the term Derelict, and Dangerous can be subjective and varies depending on the professional background and experience of the investigator undertaking the survey.

Prior to developing the app, an online questionnaire was circulated to 50 professionals in 33 different local authorities to determine if there were any problems with the definitions, to identify if there were any standards or guidelines being used and to rate indicators of site and building dilapidation.

20 out of 50 professionals responded (40% response rate). Respondents identified issues with the legal definitions of derelict sites and dangerous structures. Problems interpreting the definitions of derelict sites and dangerous structures were indicated by 55% of those polled, while 72% stating that they found the definition to be open to interpretation.
Similar legislation in relation to Derelict Sites in Northern Ireland and the UK have led to a reluctance to enforce due to a lack of guidance from the government on how it should be implemented (Department of the Environment 2016).

In order to overcome the shortcomings of the existing system a three-step solution to determining dereliction has been proposed in this research study, firstly aggregating the opinions of the group rating on each dereliction indicator to a majority to determine building and site scoring. The second step includes GIS to find the most unsuitable areas for dereliction by modelling amenities in neighbourhoods. Thirdly combining both and weighting the dilapidation scores with their impact on amenities.

2. METHODOLOGY

2.1 Determining group decision scores on dilapidation.

As there is no standard method used for determining dereliction on sites, it is important to establish a baseline from which sites can be scored. Dilapidation indicators such as holes and missing tiles in the roof, broken windows and other subjective items that could be termed as "unsightly" were drawn up in consultation with professionals working in the areas of derelict sites and dangerous structures. Common indicators used are listed in figure 1.

Potentially Dangerous	Unsightly	Other Indicators
• Partially Demolished/Ruinous Buildings • Missing Slates/Holes in the roof • Loose Masonary or falling plaster • Bow in the roof structure • Structural Cracks • Broken Windows	• Unsightly boundaries and damaged Hoarding • Graffiti • Rotten Timbers • Defective or missing gutters and downpipes • Peeling paint/ Dirty facade • Overgrown foliage • Plants growing in the masonry or roof	• Accumulation of rubbish or litter • Illegal dumping • High Tourist Areas • Unsecured site

Figure 1 Common indicators used in investigating derelict sites and dangerous structures

Site investigators were invited to rate each dilapidation indicator, Low, Low-Medium, Medium, Medium-High and High based on the level of impact they contribute to dereliction or danger on sites. 19 of the 20 respondents rated dilapidation indicators. Using linguistic quantifiers and fuzzy numbers responses were converted to numbered values from 1 to 5 with 5 being a high factor and 1 being a low factor. The group decision scores for each dilapidation indicator were determined by getting the mean value for each indicator as recommended in previous studies. (Boroushaki and Malczewski 2010; Pasi and Yager 2006; Saaty 1989).

These values were then used in FME to determine a score for the level of dilapidation on the test sites taking into account the ratings of the respondents.

2.2 Creating a mathematical model for impact on amenity.

Senior planners were asked from a planning perspective to identify areas where dereliction would impact most on amenities and identified the following criteria:

- Architectural conservation areas, where streetscapes and architectural features must be preserved.
- Record of protected structures, architectural heritage to be conserved.
- Towns and Villages, business and commercial interests to be protected.
- Commercial and business zoning.
- Approach routes into towns.
- High Tourist amenities.

- Areas of high visual sensitivity.

In addition schools, churches and population densities were also included. Population densities were categorised into four classes from low to high impact on inhabitants living in areas.

Weightings were applied to each dataset giving priority to architectural conservation areas, heritage, commercial and tourism, these are high priority areas in Tipperary. These are listed in Table 1 below

Table 1 Datasets weights and buffers chosen for each thematic map

Dataset	Geometry Type	Buffer distance (metres)	Impact Weight	Reason
High Visual Sensitivity	Polygons	n/a	20	Tourism
Architectural conservation area	Polygon	n/a	10	Architectural Heritage
Urban Visual Sensitivity	Polygons	n/a	10	Tourism
Record of Protected Structures	Points	10	10	Heritage
Commercial and business	Points	20	9	Commercial and tourism
Approach Roads to Towns	Polyline	20	8	Tourist Routes
Population Density1500 - 2500 persons per Km^2	Polygons	n/a	8	High Impact Area
Schools	Points	200	7	Public Amenity
Town Zone	Polygon	n/a	7	High Impact Area
Churches	Points	200	6	Pubic Amenity
Population Density 500 - 1500 persons per Km^2	Polygons	n/a	5	Medium impact
Population Density 100 -500 persons per Km^2	Polygons	n/a	3	Low to medium impact
Population Density 0 -100 persons per Km^2	Polygons	n/a	2	Low impact on population

In total 14 datasets were identified to be used in the model, these were available in vector format. As MCDA mapping routines use raster overlays to filter out unsuitable areas these were converted into raster format using FME. Weights as shown in table 1 were then assigned to the different geographical criteria, buffers were also applied to include areas in the proximity likely to be affected. Figure 2 shows the buffers and weights applied for each dataset.

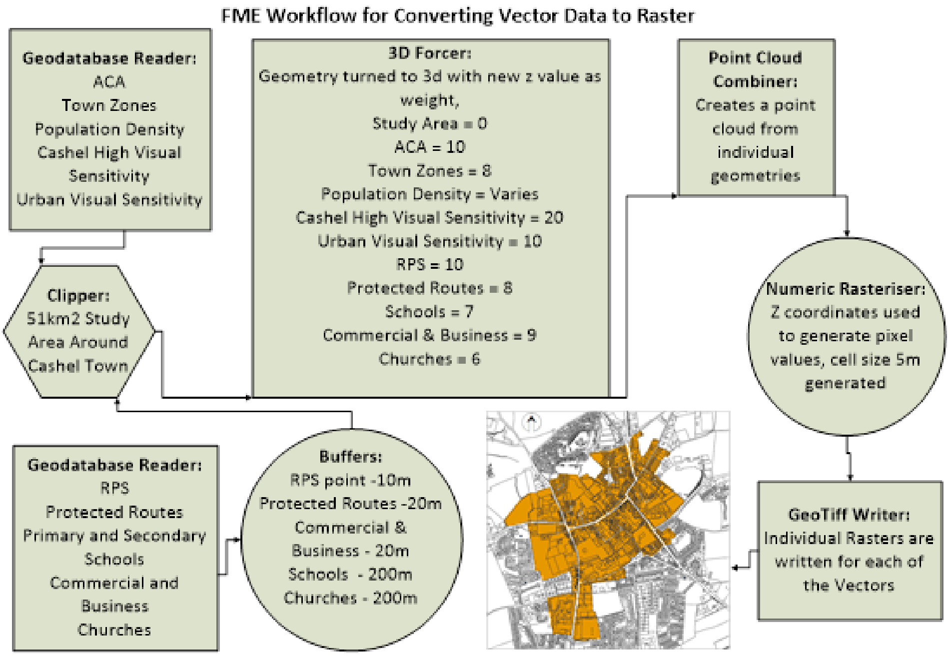

Figure 2 FME workflow for generating weighted raster maps.

These were then combined to create an impact on amenity model using FME as illustrated in Figure 3. The final model is used to scale building and site dilapidation scores, adjusting for their impact on amenity.

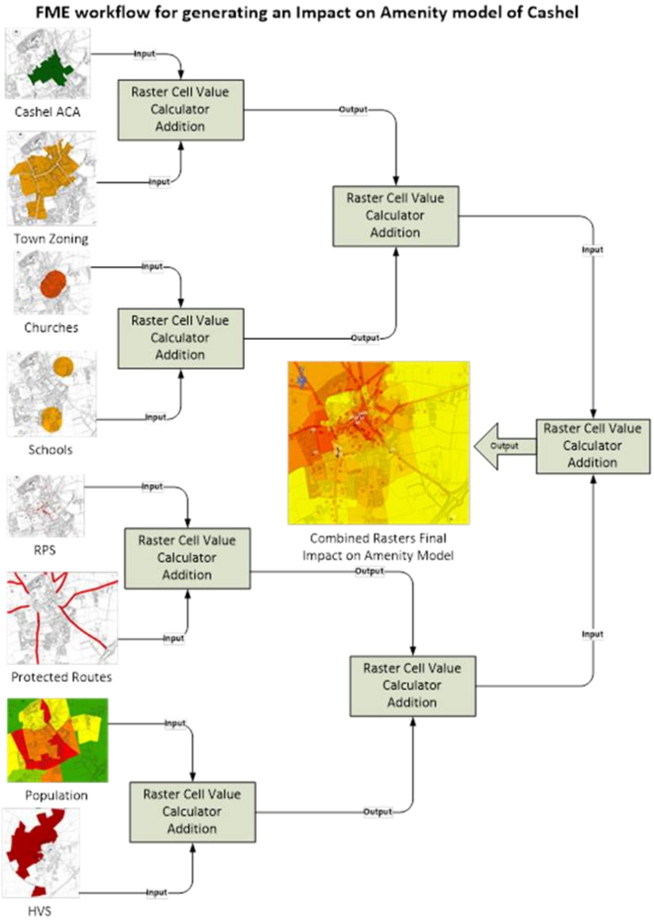

Figure 3 FME workflow for creating an impact on amenity model

The resulting impact map as illustrated in Figure 4 aggregates areas where dereliction and dangerous sites should be prioritised for remediation.

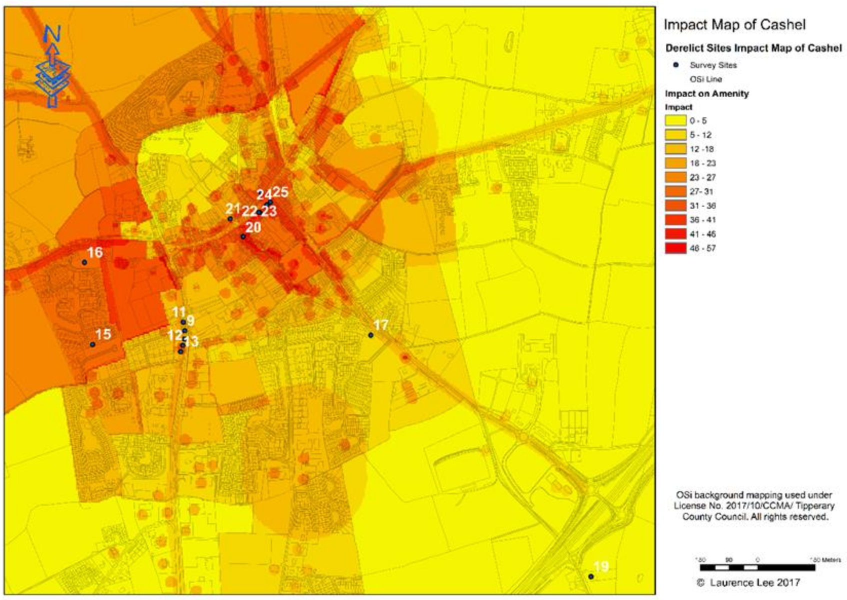

Figure 4 Impact on amenity model for Cashel, Ireland

2.3 Calculating building and site dilapidation scores

Building and site dilapidation scores are determined in the FME by totalling the building and site dilapidation encountered during the site investigation.

There are 15 main questions related to building and site dilapidation, the majority are straightforward, and the scores are calculated using FME workflows following the formula

$$T = G \tag{1}$$

where T is the building and site dilapidation score and G is the group decision score, derived from the group mean decision of experts.

Roof condition scores are calculated to take account the number of holes in the roof, and instances of slipping slates which contribute to identifying potentially dangerous buildings. These items are used to scale roof condition scores. Broken windows scoring takes account where the windows lie on the building using the following formula:

$$T=G+n\_BW \tag{2}$$

Where T is the building and site dilapidation score, G is the group decision score and n_BW is the number of broken windows. The additional number of broken windows adding to the level of dereliction.

Where the broken windows are on the ground floor a factor 'S' is applied, giving the formula,

$$T=(G+nBW)*S \tag{3}$$

Where T is the building and site dilapidation score, G = broken windows group decision score, nBW =the number of broken windows and S = a factor of 1.25. The broken windows on the ground floor contributing to the level of danger of a site and a factor of 1.25 applied increasing the scores accordingly. This is carried out in FME using a three-part conditional statement to insert a value for broken windows as observed by the investigator.

Using FME a new attribute is generated and a total dilapidation score aggregating all items identified on site is written to the geodatabase. The workflow is illustrated in Figure 5.

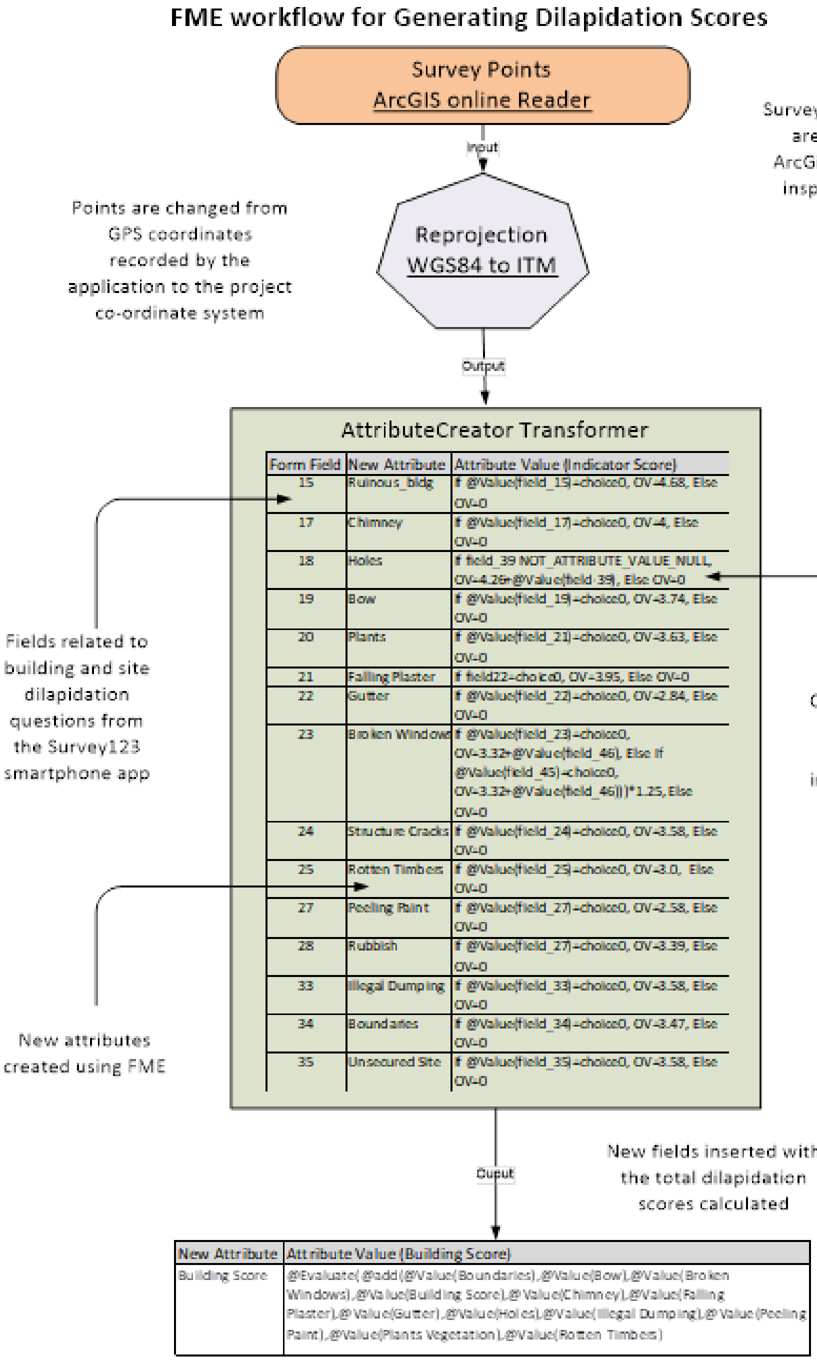

Figure 5 FME workflow for generating building and site scores.

2.4 Determining standardised site scores adjusted for amenity

The standardised site scores are derived from the overall building and site dilapidation scores and their geographical locations within the Impact on Amenity Model. Using the criteria from both, the sites are ranked in order of impact they have on the surrounding area. Using FME the cell value from the impact model at the locations of the survey points are extracted and inserted as a new attribute. A standardised site score field is generated by using the formula:

$$S=D+(IxD) \tag{4}$$

where S is the standardised site score, D is the building and site dilapidation Score and I is the normalised impact score. The calculated final scores for each site are written to the geodatabase as a feature class. Consequently, the FME processes used in this study:

- connect with the Survey123 data,
- manipulate the dilapidation indicators to generate a site dilapidation score,
- check for geographical criterion and
- outputs a final score for each site.

In addition to the spatial element, there is also a temporal element to derelict sites and dangerous structures. Given time derelict buildings become dangerous due to deterioration in structures. Ingress of water into buildings through holes in the roof and non-maintenance of rainwater goods and gutters lead to decaying timbers, structural issues and slipping slates. The application can identify potentially dangerous buildings and those that are likely to become dangerous in the future without prompt remediation. This can be built into the FME workflows when a critical combination of factors is identified on site, thus these sites can be placed into a different category to be prioritised for detailed structural examination and remediation.

The following section compares the old method of managing derelict sites in Tipperary County Council and a new solution proposed in this research.

2.5 Current method for collecting information for the Derelict Sites register

It is a requirement under legislation to keep a record of Derelict Sites by means of a register, to be made publicly available and the data presented on demand to the Government for generating statistics. When the legislation was enacted in 1990 most local authorities kept registers, records and maps in paper form. There is a government initiative to reuse existing housing stock as a partial solution to the current housing crisis to alleviate housing shortage for its citizens. These records are typically kept in paper and spreadsheet format. This method is inefficient. There is no way of discerning which sites require the most attention and remediation. The method is not efficient in keeping track of derelict sites which over time may become dangerous. The old workflow used for recording sites is illustrated in Figure 6

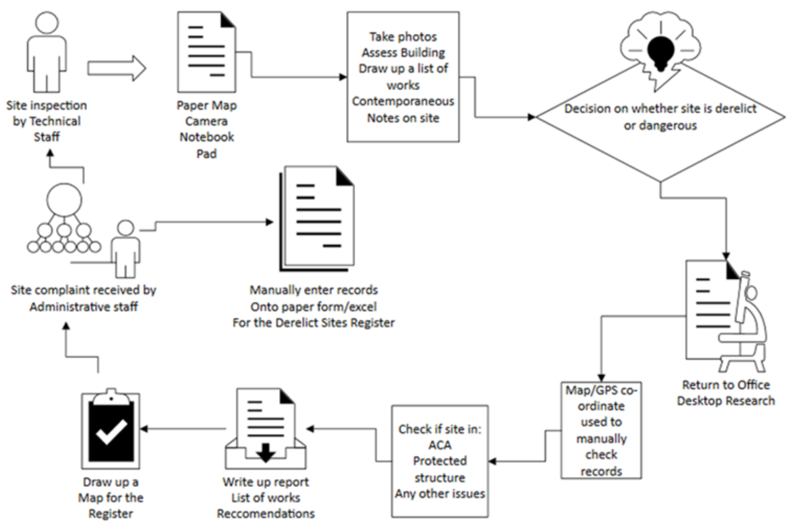

Figure 6 Current workflow used in investigating and recording sites

2.6 Proposed method for collecting information for the Derelict Sites register

A new workflow devised using ESRI's ArcGIS online database allows for a live snapshot of dereliction and danger countywide. The backend tools, using the SURVEY123 smartphone application allows the data to be recorded consistently and standard reports output automatically, saving time in the field, reducing data entry and duplication. It can also fulfil the requirements of the derelict sites register in a convenient interactive online webmap. The data can be put to use by managers, to aid better decision making in relation to Derelict Sites and Dangerous structures. The generation of standardized site scores from the programme allows for real numbers to be generated permitting the sites to be directly compared countywide. These are plotted on a webmap for graphical view. The new workflow is illustrated in Figure 7.

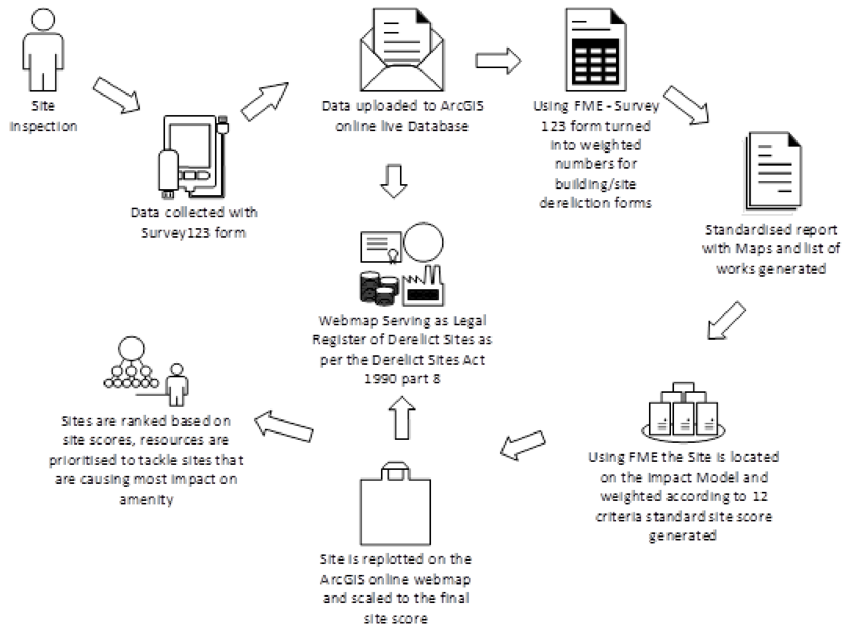

Figure 7 New workflow using web and smartphone application and FME

3. RESULTS

The prototype application was tested with two technical staff at initial test sites in Tipperary prior to site surveys in Cashel to check for the reliability of the output building scores. The initial tests showed consistency in building dilapidation scores with a 95% match, thereby indicating that subjectivity can be effectively removed from the process using the proposed method. Testing with a larger group is needed for statistical analysis.

In addition, a survey was carried out on 15 test sites in Cashel, Ireland using the Survey123 web and smartphone application and FME for recording and processing site indicators. The FME workbench was run, calculating the building scores, impact on amenity scores and the final standardised scores for all sites and outputting it to a database. There was a total of 26 criteria used in the decision-making process, 15 related to the condition of the building and site, and 11 related to the impact on amenity. The sites are ranked in the order of having the most impact on the amenity in the neighbourhood.

The workflow reliably scored sites allowing for factors like protected structures, commercial and business and tourism. Sites closer to the town centre where most of the amenities are contained were automatically scaled to score higher. Test sites on the outskirts of town and in the countryside, whereas they had high building and site dilapidation scores, they had little or no impact on amenity apart from a negligible impact on population density. These sites remained largely unchanged in the rankings.

4. CONCLUSION

Using the web and smartphone application together with Multi Criteria Decision Analysis demonstrates how dereliction can be quantified, and problems of subjectivity removed from the investigation process, thereby enabling decision making about these sites to be more scientific and objective. Used nationally it can potentially enable sites to be evaluated between different administrative areas. Ranking of sites allows managers to make better and more informed decisions when prioritising work programmes .

It allows a standard and uniform method for assessment of derelict sites and dangerous structures. It may be useful when dealing with complaints from members of the public to have a site score generated from a standard assessment. A decision can be made that low-ranking sites are dealt with informally, and higher-ranking sites are dealt with formal legal proceedings. Site scores could also be used in a courtroom when making a case for prosecution.

The use of a web and smartphone application and a workflow for generating sites scores allows for the consistent ranking of sites independent of the personal opinions of the inspector. The layout of the questions ensures that reliable reports are generated and the sites can be compared.

In addition to Web applications, FME was also used extensively in this research which was found to be quite advantageous. It increases the processing efficiency, automates the process of assigning scores and reduces the workload on the technical and administrative staff.

Desktop research back in the office can be reduced, data can be processed as they are collected and stored in the geodatabase. The output online database can act as a register under the Derelict Sites Act and be made available to the Government, and for public viewing.

The developed model can be improved in the future by using vector workflows rather than raster. This can be utilised using national vector datasets, allowing for an application to be developed on a national scale. The criteria weights chosen can be improved with the input of the opinions of more experts.

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