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The evolution of geographical information systems for fire prevention support

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ABSTRACT

Geographical information systems (GIS) provide visual map based analysis and reporting information implemented in map layers. Geographical information systems evolve by incorporating new and enhanced means of analysing and presenting location based information. In this paper we examine the evolution of a geographical information system for fire prevention support that evolved through transitions of the underlying approach to the analysis of dwelling fire risk over a six year period 2007 to 2013. The novel theoretical contribution of this paper is the examination of the evolution of GIS analysis and modelling approaches, and in the specific context of fire and rescue services, the examination of the evolution of a fire prevention support GIS.

1. Introduction

Information systems evolve in response to a change in the environment in which they operate. The geographical information system for fire prevention support studied in the research reported in this paper underwent a rapid evolution over a relatively short time period due to two main reasons. Firstly, significant budget reductions experienced by the fire and rescue service studied necessitated a significant change in the operation of the fire and rescue service, and secondly, the existing system for fire prevention support which was based upon spatial analysis of previous fire incidents was viewed as being unable to support required improvements in fire prevention.

Historically fire prevention support systems were based upon spatial analysis of fire incidence within a region [10]. In this paper we examine the evolution of a geographical information system for fire prevention support over a six year period, 2007–2013 in a fire and rescue service in the North West of England. The existing geographical information system for fire prevention support in use within the fire and rescue service studied was based upon spatial analysis of historical fire incidence combined with the level of deprivation in different areas within the region covered.

In order to respond to increased efficiency requirements necessitated by significantly reduced fire and rescue service budgets, the geographical information system for fire prevention support needed to evolve to be more predictive in nature. Multiple linear regression modelling was utilized within the geographical information system to model the probability of fire incidence based upon socio-economic causal factors associated with fire incidence. A more predictive multiple linear regression model formed the basis of the first evolution of the geographical information systems for fire prevention support within the fire and rescue service studied [33].

In order to respond to further reductions in fire and rescue service budgets, and to further enhance targeting of fire prevention activities, it was necessary for the geographical information system for fire prevention support to further evolve to move from a coarse grained geographic area based predictive approach to a finer grained socio-economic group based model. The approach utilized k-means cluster analysis of socio-economic indicators within the region studied to provide analysis of different population segments within the region via the geographical information system [34].

The population segmentation based model underlying the second evolution of the geographical information system for fire prevention support supported inter-agency working between a variety of partner public sector agencies including: the fire and rescue service studied, an NHS primary care trust, a local council and a police service. Inter-agency collaborative working was necessary in order to address not only the incidence of unintentional dwelling fire, but also the lifestyle and individual socio-economic

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causal factors underlying such fires that could not be changed by the fire and rescue service, but could however be changed by partner agencies through advocacy and referral services [35]. For example smoking cessation [22] services (offered by the NHS primary care trust) and support services for elderly and disabled individuals (provided by the local council) were utilized in order to attempt to change the lifestyle factors associated with fire risk of individuals and communities within the region studied.

The population segmentation (community profile) based model underlying the second evolution of the geographical information systems for fire prevention support also supported more targeted fire prevention by fire type analysis. For example, three of the social groups (middle income residents living in privately owned properties, young families with high benefit need, and younger urban population with high levels of deprivation) were identified as being at a greater risk of dwelling fire instance.

The novel theoretical contribution of the research reported in this paper is the examination of the evolution of GIS analysis and modelling approaches, and in the specific context of fire and rescue services, the examination of the evolution of a GIS for fire prevention support over a six year period.

2. Literature review

The literature review was undertaken by the authors of the paper who work for a university, and the fire and rescue service studied.

2.1. Systems evolution

During their lifetime, information systems are subject to a process of evolution, mainly caused by changes in the business processes of the organization [28]. Jarke et al. [16] commented upon the dynamic evolution of information systems over time that includes both incremental and evolutionary changes. Lyytinen and Newman, [19] identified both incremental and evolutionary socio-technical change in the context of information systems at multiple levels: the work system level, the building system level, and the organizational environment. Lyytinen and Newman, [19] advocated the use of socio-technical event sequences and their properties to explain how a change outcome emerged. The critical events in these sequences correspond to gaps in socio-technical systems. By considering the information system change as a multi-level and punctuated sequence of socio-technical events (evolutionary stages), it is possible to analyse the evolution of an information system. Cook et al. [4] discussed a classification scheme for evolution in software systems that considered the aspects of: continuing change, increasing complexity, self-regulation, conservation of organizational stability, conservation of familiarity, continuing growth, declining quality and feedback systems in systems evolution.

The majority of studies of software development processes explore initial development rather than ongoing software maintenance, yet the majority of the systems development budget in many organizations is devoted to maintenance. Software maintenance projects differ significantly from original development projects, indicating a need for more research specifically concerning evolutionary processes [9]. However, there appears to have been a little if any research concerning the evolutionary development of geographical information systems, and in particular concerning the evolution of geographical information systems for fire prevention support.

2.2. Fire prevention

Fire prevention strategies [29,25] have played an important part in efforts to reduce fire incidence in many countries. Crawford [7] commented that continual reassessment and adjustment of fire prevention activities is necessary in order to attempt to provide a long term solution for reducing fire deaths, injuries and property damage. Fire and rescue services typically target fire prevention initiatives at those individuals, and social groups which are estimated to have a higher risk of fire incidence [8].

Previous research identified that dwelling fires are not uniformly spread amongst the population, but are more likely to occur in communities with a high proportion of individuals from at risk groups such as the elderly, the disabled, and the deprived [2,32,12]. A more detailed understanding of the relationships between population characteristics and the risk of dwelling fire would enable fire and rescue services to make informed decisions regarding fire prevention activities.

Current fire risk models adopted by UK fire and rescue services as part of their integrated risk management planning [15] approach typically involve the analysis of previous incidence of fires, combined with indices of multiple deprivation [14]. The Fire Services Emergency Cover (FSEC) model of fire risk used by some UK fire and rescue services [10] covers dwelling fire risk, as well as other types of risk. The dwelling risk approach uses previous dwelling fire incident data, resource locations and time taken to travel to dwelling fire incidents, and analyses the relationship between response time and dwelling fire fatality rates.

2.3. Geographical information systems for fire prevention support

Geographical information systems (GIS) form a research and development area that involves diverse academic fields including geography, mathematical modelling and computer science [3]. The analytical capabilities of geographical information systems are evolving, and range from visual to exploratory and modelling methods [27]. Obermeyer [24] commented that the field of geographic information systems is maturing as a profession. Geographical information systems provide spatial and themed queries (relating to bands of values of a given set of variables across a geographical area) that are not typically provided by other forms of information systems. The map based nature of geographical information systems provides information and analyses in a highly visual manner, which cannot typically be clearly and easily provided by other means. Geographic information systems have been commonly used in local government for some time [26].

Geographical information systems are evolving to model increasingly complex social simulations and ease of management of the updating of their underlying datasets [17]. Tomlinson [31] commented that although individual geographic information systems themselves tend to evolve over time, geographic information systems also have value as a facilitator for organizational evolution. Nedovic-Budic et al. [21] stated that the sharing of geographic data between organizations remains largely resisted despite the obvious benefits that could be derived. Geographical information systems have been used by fire and rescue services for functions including identifying suitable locations or boundaries for fire stations [5] and for fire vehicle dispatch. Geographical information systems have been used for modelling forest fires [6,1] however, there appears to have been a little use of geographical information systems for modelling dwelling fires [5].

3. Research method

The research reported in this paper concerned the examination of the evolution of a geographical information system for fire prevention support over a six year period (2007–2013). The case study research method [11] was adopted. The case study research method was an appropriate choice of research method, as it allowed an in-depth qualitative examination of the evolution of