Acceptance of open source geospatial software: assessing QGIS in South Africa with the UTAUT2 model

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Abstract

Geospatial information and technologies are widely used in South Africa, initially, mostly with proprietary software but today, mature, open-source alternatives, such as QGIS, are available. We wanted to find out if and why South African users accepted QGIS, globally the most widely used free and open source geographic information system (GIS). We adapted the extended unified theory of acceptance and use of technology (UTAUT2) model to test several hypotheses regarding the acceptance and use of QGIS in South Africa. 205 registered members of the Geo-Information Society of South Africa (GISSA) completed a structured questionnaire. Results show that habit has the most significant influence on behavioural intention to use QGIS, followed by facilitating conditions, price value and social influence. Performance expectancy, effort expectancy, hedonic motivation and access to source code played no significant role. The findings show that adoption of QGIS in South Africa is not primarily influenced by benefits attributed to open source software, such as cost benefits, customizability, improved reliability, quality and security. The results are useful for developers of any GIS product and for choosing a GIS product for an organization, because they provide insight into behavioural intentions of users.

Keywords

open source, GIS, QGIS, technology acceptance, UTAUT2, South Africa

1. Introduction

Geospatial information is indispensable for sustainable resource planning and the management of urban areas. The move from paper maps to digital information in the late twentieth century gave rise to geographic information systems (GIS) through which geospatial information is collected, stored, processed, analysed and visualized (Coetzee et al., 2013; Goodchild, 2018). Initially, mostly proprietary software products were used, but the last twenty years have seen a rapid increase in the development and use of free and open source (FOSS) products for geospatial information (FOSSGIS) (Steiniger & Bocher, 2009). Community driven FOSSGIS products have matured and while there was resistance and apathy towards the adoption of FOSSGIS in the past, today, governments and organizations are increasingly incorporating FOSSGIS products into their geospatial information operations and service provision (Coetzee et al., 2020; Lawrence, 2013). Amongst others, the United Nations (UN) Open GIS initiative, established in 2016, identifies and develops FOSSGIS products that meet the requirements of UN operations for peace building and peace keeping (UN Open GIS, 2020).

According to the Open Source Initiative (2016), an open source license allows specific software to be "freely used, modified and shared". Many benefits of open source software are promoted, including cost benefits because there are no licensing fees (Balter, 2015; Bridge, 2017; Bromhead, 2017; Gray, 2017; Noyes, 2010; Wheeler, 2015); a large global community of developers and users providing support (Bromhead, 2017; Noyes, 2010); transparency because one has access to the source code (Balter, 2015; Bromhead, 2017); better quality and reliability because a global community contributes to the code, not just one team in one company (Balter, 2015; Bridge, 2017; Bromhead, 2017; Noyes, 2010; Wheeler, 2015); improved security because the large community of contributors thoroughly reviews code before it is accepted (Bridge, 2017; Bromhead, 2017; Gray, 2017; Wheeler, 2015); customizability because software can be adapted for one's own needs (Bridge, 2017; Gray, 2017; Noyes, 2010); and no vendor lock-in because a single vendor cannot hold an organization at ransom, e.g. by increasing licensing fees once the software has been adopted and integrated (Bridge, 2017; Bromhead, 2017; Noyes, 2010; Wheeler, 2015). As far back as 2003, a report by the United Nations Conference on Trade and Development acknowledged that 'open source could boost the ICT sector in developing countries' (UNCTAD, 2003). The word *free* does not refer only to monetary terms, it refers also to the freedom to access, share and distribute a certain software's source code without legal retribution. According to Stallman (2002), the term *free* refers to *liberty,* not *price*.

Even though the origins of open source geospatial software go back to 1978 when the US Department of the Interior developed a vector-based GIS, the Map Overlay and Statistical System (MOSS) (Calamito, 2017; OSGeo, 2019), the release of Geographic Resources Support Systems (GRASS) in the early 1980s is generally considered as the onset of open source geospatial software development (Coetzee et al., 2020; Donnelly, 2010). The first version of GRASS was developed for the US Army Corps of Engineers Resource Laboratory (CERL) in 1982. Later, product development was transferred to a non-profit team of researchers from Baylor University, University of Hannover and University of Illinois. The past four decades of FOSSGIS development has its genesis in GRASS, which is still widely used for geospatial analysis, processing, modelling and cartography by researchers and practitioners.

The release of QGIS in 2002 came as next big milestone for FOSSGIS development. Initially the software was called Quantum GIS; in 2013, version (2.0) was renamed to QGIS. QGIS is a volunteer-driven project, available under the GNU General Public License (see section 2.1.1), and one of the Open Source Geospatial Foundation (OSGeo) projects. QGIS supports a large variety of data models (vector, raster, etc.), databases, runs on various operating systems (Linux, UNIX, Mac OSX, MS Windows and Android) and is available in 42 languages (Khan & Mohiuddin, 2018). QGIS core functionalities can be expanded by installing plugins directly from the Internet through the QGIS Plugin Manager. The QGIS version available when this research was conducted was version 3.12 – Bucureşti, released on 21 February 2020 (QGIS, 2020). Besides online training courses, training material and blogs, several South African companies offer QGIS training (Kartoza, 2020; Spatial Modelling Solutions, 2020).

Migrating to FOSS can be hindered by technical challenges (such as support, inter-operability and security) or non-technical challenges (such as procurement, language support and human factors). Inertia or even hostility to change are human factors that can play a significant role when users have to migrate to unfamiliar FOSS products. Geospatial practitioners, like any other users, are often reluctant to change for fear of the unknown, even if the software offers significant benefits (ElHag & Abushama, 2009). In other parts of the world, researchers have found reluctance to migrate to FOSS even if it is mandated or encouraged by a government (Shaw, 2011). South Africa's Policy on Free and Open Source Software Use for South African Government (South Africa, 2006) has been in place for over a decade, but implementation of the policy has not taken off (Meintjies, 2018). Even worse, the National e-Government Strategy and Roadmap includes "open source software" in its glossary – but makes no other mention at all of open source (South Africa, 2017). It appears that a survey of FOSS across South Africa has not been done yet. In one study, Chidoori and Van Belle (2018) investigated eight small and medium-sized enterprises (SMEs) in the Western Cape and found that the availability and level of support that local companies (over and above online resources) could provide on FOSS products affected the SME's attitude towards FOSS adoption.

Anecdotally, it appears that the adoption of FOSSGIS has been slow in South Africa, despite value and benefits perceived in other countries, suggesting that perceptions are a deciding factor. A 2018 questionnaire distributed to professionals in the geospatial industry in all nine provinces of South Africa revealed that while most professionals used proprietary platforms most of the time, there is evidence of an uptake in FOSSGIS and only 14% of participants had never used FOSSGIS (Coetzee et al., 2018). A study on the practical feasibility of QGIS in military operations found that QGIS could perform the same functionality as a proprietary product, yet, the perception among users was that QGIS was not mature enough to be used in military operations (Henrico et al., 2020). These studies do not reveal why FOSSGIS products are adopted (or not) in South Africa, and we therefore conducted research to shed light on this. Our study focussed on QGIS only because the reasons for adoption of other FOSSGIS products, such as PostGIS, an object-relational database management system for geospatial information (https://postgis.net/), GeoNode, a content management system for sharing geospatial information (http://geonode.org/), or MapWindow, a desktop GIS available on the Microsoft Windows operating system only (https://www.mapwindow.org/), are likely to be very different.

The information systems (IS) literature outlines a diversity of theories and models for testing technology acceptance in a wide variety of fields (Abdellah et al., 2016; Alshehri, 2012; El-Masri & Tarhini, 2017; Mohamadali & Garibaldi, 2010; Morosan & DeFranco, 2016; Oye et al., 2012). These have been applied in many studies, and reviews of the models have been published (Alshehri, 2012; Chang, 2012; Lai, 2017; Williams et al., 2011). Based on an extensive review of this literature, the extended unified theory of acceptance and use of technology (UTAUT2) was identified as best suited for this study due to its improved variance and the inclusion of a price value construct, deemed important for testing acceptance of FOSSGIS. For the QGIS study, the UTAUT2 model was adapted to include aspects that are unique to FOSSGIS.

The study is reported in the paper as follows: the next section provides a brief overview of the UTAUT2 model, reasons for selecting the model and how the model was adapted for this study; and the following sections present the methods for conducting the study, the data analysis and results, the discussion of the results and the conclusions, respectively.

2. Research model and hypotheses

2.1 Reasons for using the UTAUT2 model in this study

Understanding technology acceptance is important for assessing technology usefulness and has been discussed, studied and reviewed in a wide variety of fields. Models and theories that enable researchers to study technology acceptance have evolved expanded over the years and have been tested extensively, including the diffusion of innovation (Rogers, 2003), theory of reasoned action (TRA) (Ajzen & Fishbein, 1988) and the technology acceptance model (TAM) (Davis et al., 1989).

The unified theory of acceptance and use of technology (UTAUT) model was an attempt to unify and strengthen theories about technology acceptance (Ajzen & Fishbein, 1988; Davis et al., 1989; Rogers, 2003; Venkatesh & Davis, 2000). The model has been applied and tested with a diverse range of technologies, including online shopping (An et al., 2016), mobile banking services (Gharaibeh et al., 2018), mapping apps (Gupta & Dogra, 2017), NFC mobile payments in hotels (Morosan & DeFranco, 2016), social recommender systems (Oechslein et al., 2014), desktop based computer software (Sharma & Kumar, 2012) and health and fitness apps (Yuan et al., 2015). Venkatesh et al. (2003) incorporated three additional constructs, namely hedonic motivation, price value, and habit, extending UTAUT into UTAUT2, also known as the Extended Unified Theory of Acceptance and Use of Technology. The extensions improved the variance explained in behavioural intention (56% to 74%) and technology use (40 % to 52 %). Table 1 lists definitions from the literature for the UTAUT2 constructs. The constructs in the model reflect the perceptions of respondents and thus represent predictors of the behavioural intention of users. The constructs should not be interpreted as objective measures of QGIS functionality.

Table 1. Constructs in the UTAUT2 model

Construct	Definition
Performance Expectancy (PE)	"the degree to which a person believes that a particular system will help to attain advances in job performance" (Venkatesh et al., 2016)
Effort Expectancy (EE)	"the degree of ease associated with consumers' use of technology"(Venkatesh et al., 2012)
Social Influence (SI)	"the degree to which an individual perceived that important others believe he or she should use the new system" (Venkatesh et al., 2003)
Hedonic Motivation (HM)	"the fun or pleasure derived from using a technology, and it has been shown to play an important role in determining technology acceptance and use" (Venkatesh et al., 2012)
Price Value (PV)	"consumers' cognitive trade-off between the perceived benefits of the applications and the monetary cost for using them" (Venkatesh et al., 2012)
Habit (H)	"the extent to which people tend to perform behaviours automatically because of learning" (Venkatesh et al., 2012)
Facilitating Conditions (FC)	"the consumers' perception of available support when using the consumer system" (Venkatesh et al., 2016)

The UTAUT2 model was selected in preference to UTAUT and other models because it provides a clear and comprehensive picture of perceptions, a measure of behavioural intentions, and it considers social influences that may guide these perceptions. The UTAUT2 model also has a strong connection to consumers, reflected by the price value and habit constructs. The price value construct is important when testing FOSSGIS, since the software is freely available and the relationship between habit and behavioural intention is of interest as we suspected habit to be a deciding factor. Further, while UTAUT2 has been used primarily to assess the acceptance of a technology users are not currently using, in our research we assess the acceptance of a technology they are familiar with but with a different user interface.

In many studies, the UTAUT or UTAUT2 model was adapted to suit the specific aspects of the technologies studied (Morosan & DeFranco, 2016), e.g. by removing from, or adding to, the models, certain constructs or moderators, in order to capture aspects related to a specific technology. A similar approach was followed in this study. Some studies have focussed on free and open source applications (Abdellah et al., 2016), but none were found with a focus on FOSSGIS and/or South Africa. GIS, and more specifically FOSSGIS and QGIS, has unique characteristics that makes it different from other technologies previously tested. The UTAUT2 model was adapted for these unique characteristics as detailed in the subsequent section.

2.2 Adaptation of the UTAUT2 model for this study

The UTAUT2 model was adapted by adding two constructs, *source code* and *software support*. The three UTAUT2 moderators were included, namely *age, gender and experience*; two additional moderators were added, namely *education* and *SAGC registration*. The effect of the moderators on all the constructs was tested in order to get a comprehensive picture. The hypotheses for this study, based on these constructs and moderators, are illustrated in Figure 1. Behavioural intention is the dependent variable used in this model. According to Mardiana et al. (2015) 'intention to use' can be interpreted as a user's willingness to use a specific technology, in this case QGIS. Behavioural intention is therefore also seen as a good overall predictor for actual system use and therefore no other controlling variable was used in this study. This is in line with other studies that also used behavioural intention as the only dependent variable (Alalwan et al., 2015; Morosan & DeFranco, 2016; Oechslein et al., 2014; Raman & Don, 2013). Each hypothesis is explained in more detail in the text.

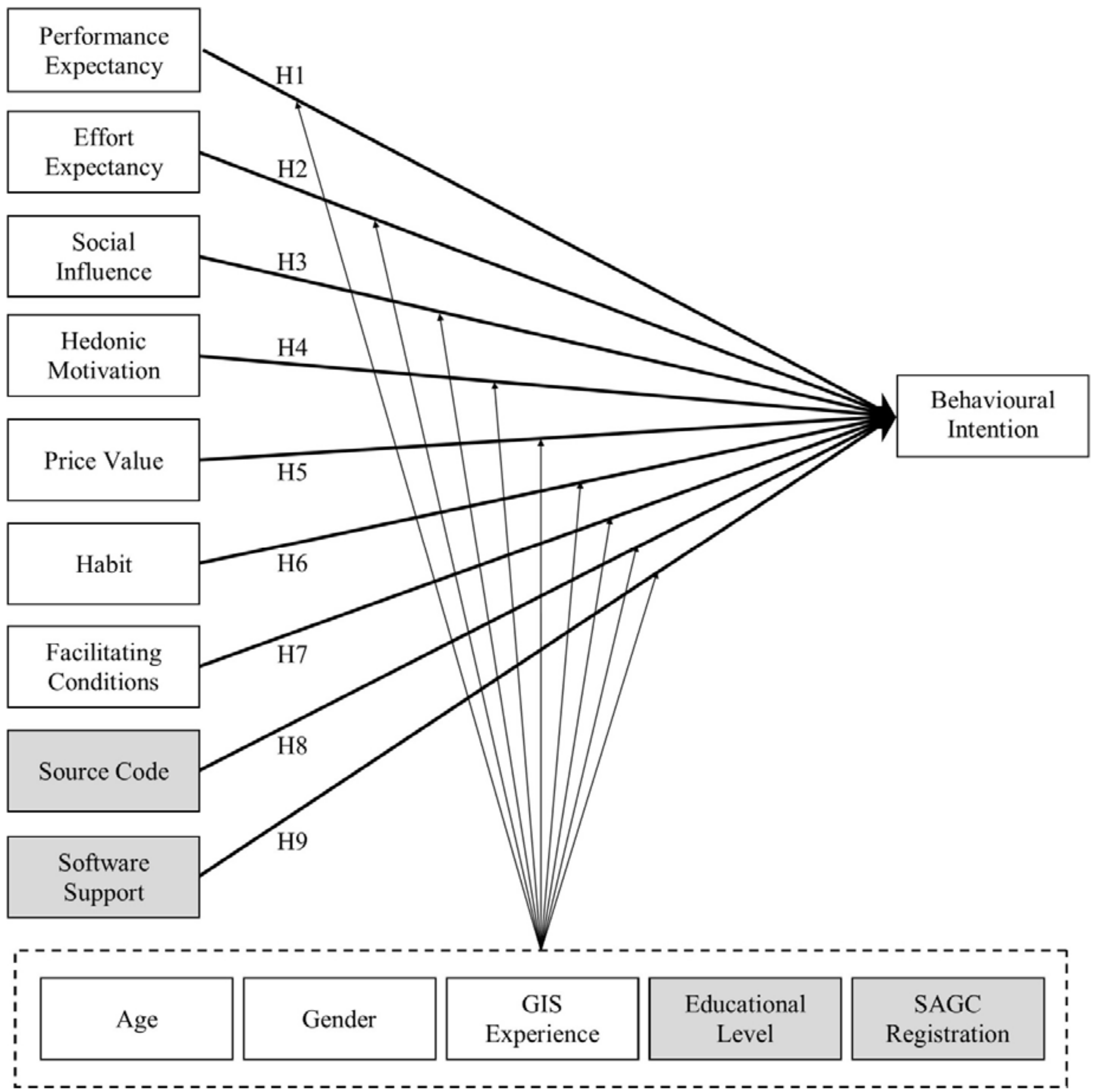

Figure 1. Hypotheses for this study, adapted from UTAUT2 in Venkatesh et al. (2012). Additional constructs and moderators are shaded in grey

2.2.1 Performance expectancy

If users believe that a certain GIS product can help them to attain better advances in the workplace, they might favourably consider that product. Examples of performance expectancy in the GIS field include the degree to which a person believes that the software can reliably perform tasks such as digitising, georeferencing, image classification, complex geospatial analysis and modelling, and scripting, which will help them to attain advances in job performance. It is therefore postulated that:

H1: Performance expectancy (PE) has a significant impact on a user's behavioural intention to use QGIS.

2.2.2 Effort expectancy

If it becomes too difficult to use a particular technology, users might simply decide not to use it. In the GIS environment this relates to the user-friendliness of the product. An example of ease of use is the ability to quickly measure the dimensions of a feature in an appropriate unit of measurement. It is therefore postulated that:

H2: Effort expectancy (EE) has a significant impact on a user's behavioural intention to use QGIS.

2.2.3 Social influence

This construct highlights the important role that people who are important to us, e.g. a supervisor, colleague or geographic information science (GISc) professional, play in our decision to accept a certain technology. Interestingly, literature suggests that as the familiarity and "experience with technology" increases, the "social influence reduces over time" (Morris & Venkatesh, 2000; Venkatesh et al., 2003). Transferred to our study, this implies that the more someone uses a certain GIS product, the less likely they are to be influenced by others to use a different product. Venkatesh et al. (2003) found that social influence was more significant when the use of a technology was mandated (and not when the use was voluntary). That is, if the use of a certain GIS product is prescribed in a workplace, social influence will have a more significant effect on the decision to use it. It is therefore postulated that:

H3: Social influence (SI) has a significant impact on a user's behavioural intention to use QGIS.

2.2.4 Hedonic motivation

Hedonic motivation is one of the constructs added to the UTAUT2 model by Venkatesh et al. (2012) who argued that intrinsic utilities (i.e. joy, fun, playfulness, entertaining, and enjoyment) play a crucial role in accelerating the adoption of a new technology. Other studies have confirmed this (H. Kim et al., 2007; Moorthy et al., 2019). An example of hedonic motivation in the GIS field could be a cloud-based tool that requires minimal effort and time to process complex geospatial information, thereby converting an arduous task into a playful activity. It is therefore postulated that:

H4: Hedonic motivation (HM) has a significant impact on a user's behavioural intention to use QGIS.

2.2.5 Price value

Price value is another construct added to the UTAUT2 model by Venkatesh et al. (2012) who stated that individual consumers were more sensitive to monetary costs than corporate employees, because corporate employees do not pay for the technology from their own pockets. Even if a GIS product is paid for by the employer, access to add-on functionality may place an additional financial burden on the employer. Therefore, the economic conditions in a country could play a role in the decision to use a particular GIS product. It seems that technical support and the cost thereof also play a role when considering price value of FOSS in South Africa (Chidoori & Van Belle, 2018). Some people may use FOSS because they believe fundamentally that software should not come with a price tag; in other words, the use of FOSS is a moral or ethical conviction – the statement 'I use QGIS because it is free' was therefore included in the questionnaire. Yet, for others, the fact that QGIS is free could be an indicator that it is a poor quality product, hence the statements, 'QGIS is good value considering that it is free' and 'QGIS is good value despite the fact that it is free'. It is therefore postulated that:

H5: Price value (PV) has a significant impact on a user's behavioural intention to use QGIS.

2.2.6 Habit

Repeating historical behaviour is a key precursor of current action (Ajzen, 1985), and this also applies to the preference to use a certain technology (Kim et al., 2008). Some geospatial analysis and modelling can be rather complex, therefore one can expect users to use a tool with which they have had success in the past. It is therefore postulated that:

H6: Habit (H) has a significant impact on a user's behavioural intention to use QGIS.

2.2.7 Facilitating conditions

For GIS, this factor relates to whether the user has the resources, skills and knowledge to complete tasks at hand. Facilitating conditions include the compatibility of the product with other geospatial technologies and data, i.e. interoperability: Can the software handle data from other sources and in different file formats? Can the software run on the available hardware and operating system? It is therefore postulated that:

H7: Facilitating conditions (FC) has a significant impact on a user's behavioural intention to use QGIS.

2.2.8 Source code

For this study, access to source code was added as a construct because the source code for FOSS products is freely available. This gives developers and users the ability to use, share, adapt and contribute to the product. This accelerates the development cycle because additional functionality can be developed and shared as and when necessary. It also gives users some form of control over the product, albeit only if they have the time, skills and/or funds to alter the source code. It is therefore postulated that:

H8: Access to source code (SC) has a significant impact on a user's behavioural intention to use QGIS.

2.2.9 Software support

According to Eldrandaly (2007), it is essential to consider the quality of vendor support and its related characteristics when choosing a GIS. This includes vendor specific criteria such as the "quality of support services, costs of support services, delivery lead time, vendor's experience in related products; vendor's experience in the application area, vendor's training capabilities, problem solving capabilities, and vendor's reputation." Technical support was therefore added as a construct to the UTAUT2 model. In the case of FOSSGIS, a user typically gets support from online resources provided by an online community. It is therefore postulated that:

H9: Software support (SS) has a significant impact on a user's behavioural intention to use FOSSGIS.

3. Methods

3.1 Overview

To investigate which factors have a significant influence on the behavioural intention of South African geospatial professionals to use QGIS, a questionnaire based on the adapted UTAUT2 model was handed out to members of the Geo-Information Society of South Africa (GISSA). The aim of GISSA is to "unify South Africans with an interest in Geo-Information Science and act as an umbrella body for its members”[1]. Members work in the public or private sector, and at universities. 65.4% of the members who participated in this study were also registered with the South Africa Geomatics Council (SAGC), the professional body for geomatics practitioners, which implies that they have completed at least three years of tertiary education.

3.2 Survey instrument

The UTAUT2 questionnaire (Venkatesh et al., 2012) was adapted to suit the specific needs of this study (by formulating the questions to test for acceptance and use of QGIS) and to include the constructs and moderators of the adapted model. The first part of the questionnaire consisted of demographic questions about the participant relating to their age, gender, years of experience with GIS and QGIS respectively, educational level and professional registration with SAGC. The latter part of the questionnaire had questions relating to the model constructs (see Table 2), measured on a 5-point Likert scale from strongly disagree to strongly agree. The questions have been grouped according to the seven UTAUT2 constructs (as given in Table 1, PE, EE, SI, HM, H, PV and FC), the two we added (SC and SS) and behavioural intention (BI). The focus of the study was on the *intention* to use one particular technology option (QGIS) from amongst several, rather than on the actual software solutions currently used by survey participants.

Table 2. Second part of the questionnaire

Code	Item
	Performance Expectancy
PE1	I find QGIS useful in my daily life.
PE2	Using QGIS helps me to accomplish GIS tasks more quickly.
PE3	Using QGIS increases my productivity.
PE4	Using QGIS increases my performance because I have access to more advanced functionalities.
	Effort Expectancy
*EE1	Learning to use QGIS is easy for me.
*EE2	Learning to use QGIS takes too much time from my normal duties.
EE3	Training material for QGIS is easy to find.
*EE4	Training courses for QGIS are easy to find.
EE5	It is easy for me to become skilful at using QGIS.
EE6	Overall, I find QGIS easy to use.
	Social Influence

[1] http://gissa.org.za/ (accessed on 16 August 2019).

SI1	People whose opinions I value prefer that I use QGIS.
SI2	People that are important to me think that I should use QGIS.
*SI3	I would only use QGIS if I needed to.
*SI4	I would only use QGIS if my job prescribe the software.
	Hedonic Motivation
HM1	Using QGIS is fun.
HM2	QGIS is a user-friendly product.
HM3	Using QGIS is very entertaining.
	Price Value
PV1	QGIS is good value considering that it is free.
PV2	I use QGIS because it is free.
PV3	QGIS is good value despite the fact that it is free.
	Habit
H1	The use of QGIS has become a habit for me.
*H2	I am addicted to using QGIS.
*H3	I must use QGIS.
*H4	I must use QGIS because my work environment prescribes it.
H5	The use of QGIS when viewing data has become a habit to me.
H6	The use of QGIS when digitising has become a habit to me.
H7	The use of QGIS to do analysis tasks has become a habit to me.
	Source Code
*SC1	The fact that the QGIS source code is openly shared motivates me to use QGIS.
SC2	I use the QGIS source code to understand how the software works.
SC3	I use the QGIS source code to customize the product for my own purposes.
SC4	I contribute to QGIS source code to improve the product.
*SC5	If the QGIS source code is no longer available, I will stop using QGIS.
	Software Support
*SS1	The software support for QGIS products is good.
*SS2	The software support for QGIS is expensive.
*SS3	I know who to contact when I need software support for QGIS.
*SS4	I constantly need face-to-face software support for my GIS work projects.
*SS5	Software support that the internet offers (blogs, on-line manuals, videos and tutorials etc.) in terms of QGIS is more than enough for me.
	Facilitating Conditions
*FC1	I have the resources necessary to use QGIS.
*FC2	I have the knowledge necessary to use QGIS.
FC3	QGIS is compatible with other geospatial technologies I use.
FC4	QGIS is compatible with all the data I use.
FC5	QGIS is compatible with the geospatial databases I use.
	Behavioural Intention
BI1	I intend to start using QGIS in the future.
BI2	I always try to use QGIS in my daily work.
BI3	I intend to continue to use QGIS in the future.

* denotes items eliminated during reliability and validity analysis, and modification of the measurement model.

3.3 Procedure

A cross-sectional study was conducted among active GISSA members. In 2019, 295 hardcopies of the questionnaire were handed out at selected GISSA regional meetings, as well as at the national meeting. 205 responses were deemed to be valid. In 2019, GISSA had 721 active members; 205 valid responses amount to 28% of all GISSA members. As part of the initial data management and screening, both numerical and descriptive means were used to evaluate the univariate distribution of each construct. The skewness and kurtosis of all constructs were between the -2 and 2 range and therefore, the distribution was normal (Gravetter & Wallnau, 2005; Trochim & Donnelly, 2007). The histograms were also analysed and no kurtosis issues were found. Reliability and validity testing was done in SPSS (IBM, 2020). A structural equation modelling (SEM) analysis was done in Amos version 21 (https://www.ibm.com/us-en/marketplace/structural-equation-modeling-sem).

3.4 Research ethics

Ethical clearance for this study was obtained from the University of Pretoria and all participants gave consent by means of a consent form, signed by each participant.

Table 3. Characteristics of participants (n=205)

Category	Characteristic	Frequency	Percentage
Gender	Male	112	54.6
	Female	93	45.4
Age	18 - 30 Years	48	23.4
	31 - 60 Years	149	72.7
	61 – 80 Years	8	3.9
Years of experience with GIS	0 – 5 Years	57	27.8
	More than 5 Years – 10 Years	42	20.5
	More than 10 Years – 15 Years	41	20.0
	More than 15 Years – 20 Years	27	13.2
	More than 20 Years	38	18.5
Years of experience with QGIS	No experience with QGIS	65	31.7
	1 Year	38	18.5
	2 Years	32	15.6
	Between 3 – 5 Years	46	22.4
	Between 5 – 10 Years	17	8.3
	More than 10 Years	7	3.4
Educational level	GIS courses at various institutions	14	6.8
	National Certificate	10	4.9
	National Diploma	38	18.5
	Degree	45	22.0
	Honours/4-year degree	53	25.9
	Masters	37	18.0
	PhD	8	3.9
Registration	Yes	134	65.4
	No	71	34.6
Registration category	Candidate	7	3.4
	Technician	56	27.3
	Technologist	18	8.8
	Professional	53	25.9

3.5 Participants

Most participants were in the age group of 31 – 60 years (n = 149, 72.7%); followed by the group of 18 – 30 years (n = 48, 23.4%) and the group of 61 – 80 years (n = 8, 3.9%). This distribution reflects the fact that GISSA members are typically of working age. In terms of gender, 112 (54.6%) participants were male and 93 (45.4%) female. This more or less equal distribution implies that gender specific factors will not influence our results. At least 69% of participants had experience with QGIS. Most of the participants (n = 181, 88%) also had a tertiary qualification. Further characteristics of participants are presented in Table 3.

4. Data analysis and results

4.1 Reliability and validity of the constructs

First, the data was analysed to determine its reliability and validity. For this, the Cronbach Alpha coefficient and composite reliability of each construct was determined (see Table 4). Reliability testing is crucial in order to determine whether a construct is consistent, stable and accurate. According to Alshehri (2012), Pallant (2013) and Venkatesh et al. (2016), the ideal value for both the Cronbach Alpha coefficient and composite reliability is 0.7. To improve the reliability of the measures, the items EE2, SI3, SI4, SS2 and SS4 were removed. Subsequently, inter-item correlations were determined and the SC1 item was removed because its value was less than the specified threshold value of 0.3. For validity testing, convergent and discriminant validity must be determined. For determining convergent validity, factor loadings are used to calculate the average variance extracted (AVE). The desirable threshold for AVE values is 0.50 or above (Fornell & Larker, 1981). AVE values for each construct are listed in the last column of Table 4. According to (Fornell & Larker, 1981), constructs have discriminant validity if the correlations are lower than the square root of the AVE. The diagonally placed elements in Table 5 indicate the square root of the average variance extracted (AVE).

Based on the above reliability and validity analysis, the software support construct was removed from further analysis since it did not meet the required minimum threshold value of 0.7 on the two reliability scales, i.e. one will not be able to infer from the data whether software support has an effect on behavioural intention or not. The AVE value for software support was also below the minimum threshold of 0.50, implying that the measure has insufficient variance for the items to converge into that specific construct. All other constructs were found to be reliable and valid since they exceeded the minimum requirements for Cronbach Alpha, composite reliability and AVE, and they were therefore retained for further analysis. Very high Cronbach Alpha values can indicate redundancy in constructs; see e.g. the PE and SI values in Table 4. We checked for redundancy later using the modification indices (MI) of the measurement model.

Table 4. Cronbach α, Composite Reliability and AVE scores

Construct	Cronbach Alpha	Composite Reliability	AVE
Performance Expectancy (PE)	α.917	0.899	0.749
Effort Expectancy (EE)	α.809	0.815	0.526
Social Influence (SI)	α.919	0.923	0.858
Hedonic Motivation (HM)	α.848	0.852	0.658
Price Value (PV)	α.774	0.789	0.558
Habit (H)	α.892	0.894	0.555
Source Code (SC)	α.778	0.848	0.598
Facilitating Conditions (FC)	α.769	0.845	0.523
Behavioural Intention (BI)	α.842	0.769	0.537
Software Support	α.599	0.596	0.337

From Table 5, it can be concluded that the square root of the AVE is greater than the correlation between the various constructs, meaning the measure (construct) is discriminant, and we can conclude that the constructs are unrelated to each other.

Table 5. Discriminant validity

	Construct	PE	EE	SI	HM	PV	H	SC	FC	BI
Correlations and Discriminant Validity of the Scales associated with the Model										
	PE	**.865**								
	EE	.256	**.725**							
	SI	.258	-.026	**.926**						
	HM	.386	.485	.267	**.811**					
Correlation	PV	.219	.424	.061	.353	**.747**				
	H	.657	.290	.362	.511	.203	**.745**			
	SC	.247	.023	.214	.076	-.145	.397	**.773**		
	FC	.168	.321	-.018	.217	.249	.119	-.143	**.733**	
	BI	.422	.145	.369	.317	.270	.555	.132	.215	**.732**

4.2 Measurement Model

During SEM analysis, two types of models are built: a measurement model followed by a structural model. According to Gefen et al. (2000), the measurement model represents the theory and specifies the factor loadings or measurements of constructs, the latent variables. In the measurement model, the distinction between the independent variables (PE, EE, SI, HM, PV, H, SC and FC) and the dependant variable (BI) is not yet made. The structural model indicates the relationship between the independent constructs (PE, EE, SI, HM, PV, H, SC and FC) and the dependant constructs (BI), and the magnitude of each relationship.

Factor loadings of the measurement model for this study can be found in Table 6. In order to achieve unidimensionality of a measurement model, any item with a low factor loading should be deleted (Awang, 2015a). The minimum threshold for factor loadings is specified as 0.50 (Hair et al., 2006). The factor loading for SC5 was 0.440 and it was therefore excluded from further analysis.

The indices used to determine measurement model fit were relative chi-square ($\chi 2$/df), the Comparative Fit Index (CFI), the Incremental Fit Index (IFI), the Tucker Lewis Index (TLI) and Root Mean Square Error of Approximation (RMSEA). For the relative chi-square ($\chi 2$/df) index, ratios of < 3 are acceptable and for RMSEA, values must be below or equal to 0.08. The thresholds for other indices are values > 0.90.

Table 6. Initial factor loadings (before removing redundant items)

Code	Item	Factor Loading
	Performance Expectancy	
PE1	I find QGIS useful in my daily life.	0.775
PE2	Using QGIS helps me to accomplish GIS tasks more quickly.	0.902
PE3	Using QGIS increases my productivity.	0.905
PE4	Using QGIS increases my performance because I have access to more advanced functionalities.	0.860
	Effort Expectancy	
EE1	Learning to use QGIS is easy for me.	0.539
EE3	Training material for QGIS is easy to find.	0.690
EE4	Training courses for QGIS are easy to find.	0.637
EE5	It is easy for me to become skilful at using QGIS.	0.811
EE6	Overall, I find QGIS easy to use.	0.693
	Social Influence	
SI1	People whose opinions I value prefer that I use QGIS.	0.877
SI2	People that are important to me think that I should use QGIS.	0.971
	Hedonic Motivation	
HM1	Using QGIS is fun.	0.846
HM2	QGIS is a user-friendly product.	0.755
HM3	Using QGIS is very entertaining.	0.827
	Price Value	
PV1	QGIS is good value considering that it is free.	0.708
PV2	I use QGIS because it is free.	0.668
PV3	QGIS is good value despite the fact that it is free.	0.847
	Habit	
H1	The use of QGIS has become a habit for me.	0.704
H2	I am addicted to using QGIS.	0.662
H3	I must use QGIS.	0.582
H4	I must use QGIS because my work environment prescribes it.	0.527
H5	The use of QGIS when viewing data has become a habit to me.	0.854
H6	The use of QGIS when digitising has become a habit to me.	0.902
H7	The use of QGIS to do analysis tasks has become a habit to me.	0.895
	Source Code	
SC2	I use the QGIS source code to understand how the software works.	0.898
SC3	I use the QGIS source code to customize the product for my own purposes.	0.901
SC4	I contribute to QGIS source code to improve the product.	0.762
SC5	If the QGIS source code is no longer available, I will stop using QGIS.	0.440
	Facilitating Conditions	
FC1	I have the resources necessary to use QGIS.	0.666
FC2	I have the knowledge necessary to use QGIS.	0.615
FC3	QGIS is compatible with other geospatial technologies I use.	0.808
FC4	QGIS is compatible with all the data I use.	0.808
FC5	QGIS is compatible with the geospatial databases I use.	0.716
	Behavioural Intention	
BI1	I intend to start using QGIS in the future.	0.500
BI2	I always try to use QGIS in my daily work.	0.830
BI3	I intend to continue to use QGIS in the future.	0.823

The initial measurement model did not achieve an overall good fit: $\chi 2/df = 2.357$, CFI = 0.845, IFI = 0.847, TLI = 0.824 and RMSEA = 0.082. After intense analysis of factor loadings and modification indices (MI) supplied by AMOS, items with low factor loadings and/or high MI values (above 15) were deleted "one item at a time", as prescribed by literature (Awang, 2015b), starting with the item with the lowest factor loading. High MI values usually indicate redundant items (Awang, 2015b). The constructs EE, H and FC had a sufficient number of other items, which reinforced the decision to delete the redundant items (EE1, EE3, H2, H3, H4, FC1 and FC2). After the deletion of these items, a new measurement model was prepared, which demonstrated an overall good fit: $\chi2/df = 1.824$, CFI = 0.928, IFI = 0.930, TLI = 0.914 and RMSEA = 0.064. All factor loadings for individual items were above the 0.50 threshold and therefore unidimensionality was achieved for the measurement model.

4.3 Structural Model

The structural model tests the data fit, as well as the hypothesized relationships between all the constructs. The index values confirmed a good fit of the data with the structural model; $\chi2 = 572.846$, df = 314, $\chi2/df = 1.824$, CFI = 0.928, IFI = 0.930, TLI = 0.914, and RMSEA = 0.064. The fitted model therefore consists of a specific set of parameters that can accurately define behavioural intention of users.

Table 7. Hypothesis results sorted by strength of the relationship to behavioural intention

Hypothesis	Effect	Standardised coefficient (β)	p-value	t-value	Result
H6	H → BI	0.651	0.001	5.337	Supported
H7	FC → BI	0.231	0.002	3.136	Supported
H5	PV → BI	0.270	0.004	2.900	Supported
H3	SI → BI	0.181	0.015	2.444	Supported
H1	PE → BI	0.056	0.531	0.627	Not supported
H4	HM → BI	-0.830	0.432	-0.785	Not supported
H8	SC → BI	-0.099	0.207	-1.263	Not supported
H2	EE → BI	-0.179	0.146	-1.453	Not supported

Table 7 provides a summary of the hypothesis results sorted by the standard coefficient (β), that is, the strength of the relationship to behavioural intention. When t-values are significant at $t>1.96$ for a regression weight, then that path is significant at $p<0.05$ and also if $t>2.33$ and $p<0.001$. This means that those estimated path parameters are significant. Standardized coefficient (β) is the degree of change that occurs when comparing an individual independent variable to the dependent variable and can be negative and positive. A higher β-value indicates a stronger effect between the independent and dependent variable (Statistics How To, 2020; StatisticsSolutions, 2019). The structural model in Figure 2 shows p-values of the respective constructs and their relationship to behavioural intention (BI).

The analysis of the hypothetical relationships between behavioural intention and performance expectancy (H1), effort expectancy (H2), hedonic motivation (H4) and source code (H8) respectively were not significant ($\beta = 0.056$, $p>0.05$; $\beta = -0.179$, $p>0.05$; $\beta = -0.83$, $p>0.05$; $\beta = -0.099$, $p>0.05$). The hypothesized relationships between behavioural intention and social influence (H3), price value (H5), habit (H6) and facilitating conditions (H7) respectively were supported by the results ($\beta = 0.181$, $p<0.05$; $\beta = 0.270$, $p<0.05$; $\beta = 0.651$, $p<0.001$; $\beta = 0.231$, $p<0.05$). Therefore, PE, EE, HM and SC do not have a significant effect on the behavioural intention to use QGIS, while H, FC, PV and SI (ordered by the strength of the relationship) have an impact on whether someone will use QGIS or not. R^2 was 0.62 which means that 62% of the variance in behavioural intention can be explained by the model.

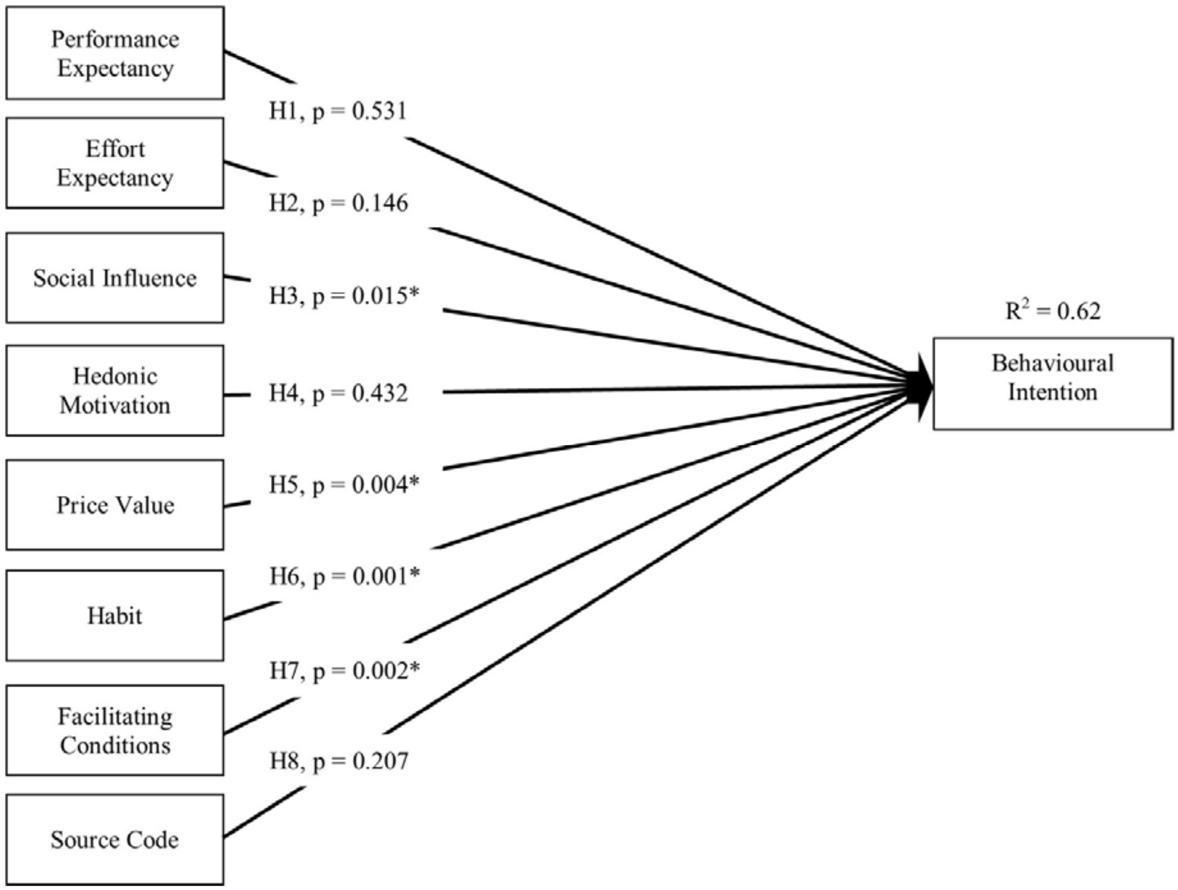

Figure 2. Structural model indicating p values for each hypothesis (* indicates significant at p < .05)

5. Discussion

Habit was found to have the most significant (strongest) influence on the behavioural intention of users, i.e. "the extent to which people tend to perform behaviours automatically because of learning" (Venkatesh et al., 2012) affects a user's intention to use QGIS the most. This could explain the relatively slow adoption of QGIS – most users are probably already very familiar with another GIS product. The finding also suggests that it is difficult to change a user's perception about a certain GIS product if they have been using that product for a long period. Herein lies a risk of stagnation: if users stick to a product out of habit, new developments and improved functionality will pass them by. To mitigate this risk, users should therefore be encouraged to regularly reflect critically on their reasons for using a GIS product and educators should expose their students to more than one GIS product, so that they learn to appreciate the specific benefits of each product, and not fall into the habit of using a single product.

Facilitating conditions play the second most significant role in the behavioural intention to use QGIS. Users want to know whether QGIS is compatible with other geospatial technologies, data and services that they use to perform their daily work. Integration with other corporate systems could be a barrier to using QGIS. This finding suggests that GIS product developers should consider geospatial data and service interoperability in their product specifications and improvements. Standards facilitate interoperability, and the development of standards for geospatial information has increasingly gained momentum in the last 20 years. It is possible that QGIS development and adoption benefited from the availability of these standards. QGIS is a project of the Open Source Geospatial Foundation (OSGeo), a not-for-profit organization with the mission to promote "global adoption of open geospatial technology" (www.osgeo.org). The importance of standards is reflected in the OSGeo incubation process, which considers whether project members are "aware of, and implement support for, relevant standards" before deciding whether a project can enter the incubation process (OSGeo, 2006).

As expected, in a developing country like South Africa, where resources are typically limited, price value had a significant influence on the intention to use QGIS, albeit this influence was not as strong as habit and facilitating conditions. This implies that the benefit of a lower total cost of ownership ranks lower than habit when users decide whether to use QGIS. It is a concern that cost benefits do not outweigh habit in an economically resource-constrained environment. While QGIS is available at no cost, support may come at an additional cost, especially if face-to-face training and support is required. When adopting QGIS, users will consider the cost of such support and compare this to the cost of paying for proprietary licences which often includes such support.

Chidoori and Van Belle (2018) confirmed that South African SMEs in the Western Cape weighed up these costs.

Finally, social influence also had a significant influence on the intention to use QGIS (albeit the lowest among the four constructs). As more people start to use QGIS, especially those that are respected in the GISc community of the country, this encourages others to use QGIS and accelerates adoption.

This study found hedonic motivation to have an insignificant effect on the intention to use QGIS. The participants in this study were GISSA members, i.e. people who use GIS in their workplace, therefore this result could be explained by the fact that they do not perceive "fun and pleasure" to be important when deciding whether to use QGIS. In the geospatial domain, one would expect hedonic motivation to affect adoption of FOSSGIS for crowdsourcing and volunteered geospatial information (Solís et al., 2017), such as MapSwipe (https://mapswipe.org/about.html) or the iD editor for OpenStreetMap (http://ideditor.com/).

Access to source code also played an insignificant role in the intention to use QGIS. Despite the fact that access to source code is promoted as a benefit of open source software, access to source code did not inspire GISSA members to use QGIS. This can be attributed to the fact that probably only few of the GISSA members have the time and skills to adapt and contribute to the source code. They are also unlikely to have funding so that others can do this for them. However, access to source code could play a role when an organization decides to use QGIS. Access to the source code would make it possible for them to influence the software development life cycle and the development of additional functionality. Funds or employees with appropriate skills are not necessarily required, but provide the capability of developing functionality to suit an organization's specific needs. The influence of access to source code could be further explored in a study that focuses on organizational adoption of QGIS.

In this study, performance expectancy was an insignificant predictor of behavioural intention to use QGIS. This is interesting, because others have found performance expectancy to be one of the main predictors of the behavioural intention to adopt a specified technology (Palau-Saumell et al., 2019). Performance expectancy relates to improved reliability, quality and security of software, benefits that are attributed to open source software. However, GISSA members were not persuaded by these benefits to use QGIS. Catherine et al. (2018) stated that this construct was comparable to the perceived usefulness construct in the TAM model and was considered fundamental in determining a person's attitude towards a specified technology. Since performance expectancy had a high correlation with habit, the finding in this study could be linked to the high significance of habit on behavioural intention to use QGIS. Once it is a habit to use a specific GIS product, improved performance of another product has to be significant to overcome the habit barrier. The exact reasons for low significance of performance expectancy in this study could be explored through interviews with participants in the study.

Effort expectancy (an individual's beliefs about the ease of effort associated with the technology) was also found to have an insignificant effect on the behavioural intention to use QGIS. Effort expectancy has a moderate correlation to habit, but a very weak correlation to behavioural intention. Whether users consider QGIS to be easy to use or not, this does not affect their decision to use QGIS.

It is a pity that software support had to be dropped from the analysis due the construct's low reliability and validity. Since support provided by a global community of users and developers is often hailed as an advantage of open source software, it would have been interesting to assess its effect on behavioural intention to use QGIS. The low reliability and validity could be due to the way in which the questions were stated, and future studies should revise these questions.

Table 8 provides a summary of constructs that influenced behavioural intention in 13 other UTAUT studies. H and FC are significant in seven studies, while PV and SI are significant in four studies. PE played a significant role in affecting BI in nine other studies, yet, it had no significant effect on geospatial practitioners' intention to use QGIS. It could be a concern that geospatial practitioners do not consider performance expectancy to be important when considering the software they use in their daily work. However, this could be because the software they use is prescribed by their workplace. Most of the studies listed here refer to technologies that are not used in the workplace. One would have to do a comprehensive literature review of UTAUT studies to better understand how our results compare to the results of other studies. However, since those studies are unlikely to involve geospatial technologies, the value of the comparison would be limited.

The results of this study provide some interesting and unexpected results. However, it was a single study in a specific region and community, and more studies are required to verify the results. For example, for this cross-sectional study, data was collected once during the span of the study. The study should be repeated in a few years' time when South African users may be more familiar with QGIS, and its use more routine or habitual. Unfortunately, one cannot go back in time to know what the outcome of the study would have been, had it been conducted in the early 2000s. The study was executed among GISSA members only because this provided relatively easy access to GISc professionals in South Africa. Repeating the study within specific organisations in South Africa or sectors of the industry would improve the confidence of the results for South Africa. Similarly, comparing the use and acceptance of QGIS in a developing country like South Africa to that in a developed country, or even another developing country, would further contribute to understanding whether the results can be generalized beyond the borders of South Africa. Finally, based on what we have seen in the South African industry, we think that most people run QGIS in a Windows operating system environment, but one could validate this with a survey, and also establish whether acceptance differs depending on the operating system. Hopefully, our study will inspire similar studies in other regions with different patterns and motivations of open source geospatial software adoption.

Table 8. Correlation to other studies' constructs that influenced behavioural intention (BI)

Study	Technology	UTAUT2 constructs that influenced BI	Other constructs that influenced BI
Gupta and Dogra (2017)	Mapping app	PE, HM, H, FC	-
Palau-Saumell et al. (2019)	Mobile apps	H, FC	-
Tak and Panwar (2017)	Mobile shopping apps	HM, H	-
Prayoonphan and Xu (2019)	Common Ticket 'Spider Card'	PE, PV, FC	-
Adel Ali and Rafie Mohd Arshad (2018)	M-learning	PE, SI, FC	Learners' autonomy (LA)
Venkatesh et al. (2012)	Mobile internet apps	HM, PV, H	-
Fadzil (2017)	Mobile app	PE, EE, SI, HM, PV, H, FC	-
Abdellah et al. (2016)	FLOSS ERP systems	PE, EE	-
Xu (2014)	Social network games	SI, PV, H	Fantasy, enjoyment, achievement
Oechslein et al. (2014)	Social recommender systems	PE	User's social network information, profile information, reading behaviour
Gharaibeh et al. (2018)	Mobile banking services	PE, EE, SI, FC	Mass media trust
Catherine et al. (2018)	Fingerprint biometrics authentication for ATMs	PE, EE, SI, FC	-
Moura et al. (2017)	Use of the Internet by the elderly for choosing a tourism destination	PE, HM, H	Trust

6. Conclusion

The study presented in this paper tested factors that influence South African professionals to use QGIS (or not), using an adaptation of the UTAUT2 model. Habit (H) had the most significant influence on a user's behavioural intention to use QGIS, followed by Facilitating Conditions (FC), Price Value (PV) and Social Influence (SI). Performance Expectancy (PE), Effort Expectancy (EE), Hedonic Motivation (HM) and Source Code (SC) played no significant role. 62% of the variance in behavioural intention can be explained by the model, which suggests that this adapted UTAUT2 model is capable of explaining a high proportion of variance of behavioural intention to accept and use QGIS.

The findings of our study show that adoption of QGIS in South Africa is not primarily influenced by the benefits attributed to open source software. Habit and facilitating conditions have a stronger influence than, for example, cost benefits and customizability. This could possibly be explained by the fact that we did not question organizations, who are concerned about costs, but individual practitioners who are more concerned with functionality required to perform tasks in their work environment. However, performance expectancy (improved reliability, quality and security) did not significantly influence their intention to use QGIS, which suggests that they do not perceive QGIS to be worth the effort of breaking their current habits.

To benefit from new technologies and developments, a way must be found to break old habits. To do this, one must understand how habits are formed in the first place. As cited by Aristotle (2019) in "The Power of Habit", a "three-step neurological pattern" forms the core of each habit. The first step in this pattern is the 'cue', a signal received by the brain to go over into automatic mode. The second step is 'routine', the behaviour and action one takes. Step 3, the 'reward', tells your brain whether it is worth remembering. To break a habit, one needs to consciously switch to routines that lead to more rewards. In the case of GIS products, one needs to encourage users to experiment with a GIS product so that they can experience the additional rewards. This could be achieved, for example, through demonstrations and hands-on sessions at conferences and other events.

The results of this study contribute to an improved understanding of why South African professionals adopt FOSSGIS products, such as QGIS. The study could be repeated in other countries or communities to understand whether there are differences in the factors that affect the use and acceptance of FOSSGIS between different countries and communities. The results of this study are useful to developers of any GIS product, whether it is an open source product or not, because they provide insight into the South African market of professional GIS users. This study could also help managers and users to find the most appropriate criteria for adopting a specific GIS product. Further studies could involve other FOSSGIS products, such as PostGIS and GeoDa, investigate organizational adoption of FOSSGIS, and also compare the adoption of other geospatial technologies to that of QGIS and to general purpose technologies. Two further considerations for future studies could be to explore the inertia in one's preferred GIS (that is, the reluctance to switch from the GIS one has learnt to use) and the extent to which the use of FOSSGIS (and its principles) has been, is, or will be incorporated into geospatial curricula at universities. Various platforms for geospatial practitioners can also assist to educate registered members on new FOSSGIS technologies.

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