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Empirical Evaluation of ArcGIS with Contemporary Open Source Solutions - A Study

Shafat Khan[1], Dr. Syed Mutahar Aaqib[2]

[1]*Research Scholar, Department of Computing & Information Technology, Himalayan University, Itanagar, Arunachal Pradesh, India.*

[2]*Assistant Professor, Department of Computer Science, A S.College, Cluster University of Srinagar, J&K, India.*

ABSTRACT

This paper provides an overview of free and open source (FOSS) geographic information system (GIS) softwares within the broader context of the open source software movement and developments in GIS. The objective of this study is to examine the advantages and disadvantages of the use of proprietary and free/open-source software involving GIS. Recently open source softwares have started playing a vital role in industry, academics and research. In the last few decades, field of GIS has witnessed a rapid transformation and has witnessed the emergence of various proprietary and open source GIS softwares. In this paper we investigate and present an analysis of open source GIS software systems against its proprietary counterparts, highlighting its strengths and weaknesses. We examine the different desktop GIS software projects in terms of their main characteristics and functionality and compare them with ArcGIS and QGIS which are one of the most popular GIS software systems today. We conclude by listing the future scope in the development of open source GIS software systems.

Keywords: GIS, Open Source GIS, ArcGIS, QGIS.

I. INTRODUCTION

In day-to-day life, we must have availed services such as door-step pizza delivery, emergency medical services, real-time flight information, and tracking and delivery of shipments on time. Most organizations such as fast-food chains, hospitals, banks and the aviation industry, use Geographic Information System (GIS) and other automated systems to provide real-time professional services to their customers. Organizations use GIS as a decision-support-system. For Example, banks can use GIS to analyze the population density in a state and decide whether or not to install new automated teller machines (ATM) in specific areas, to increase their customer base. [1]

GIS has evolved from custom programs created by government agencies on mainframe computers within the Nineteen Sixties, to non-public desktop based mostly software system within the Eighties, to integrate net based mostly solutions within the 2000s. Desktop GIS software system continues to be common because it permits users to govern free downloadable information and to form their own information in a limitless approach, as against an internet mapping application wherever the user is proscribed to what the designer provides. The

desktop GIS market consists of a few of corporations, like Intergraph, MapInfo, and ESRI that make proprietary software system. ESRI, the creators of the popular ArcGIS software system, is that the largest company within the GIS business and provides software system, support, consulting, training, and publications. [2]

GIS software is not only provided by companies but increasingly also by free and open source software projects.

1.1 What is open source software?

A couple of terms, like 'proprietary', 'free' and 'General Public License (GPL)', are usually used with relevancy open source software. Figure 1 that has been adopted from Chao-Kuei provides a structured summary on the ordinarily used terms. It's to ascertain that the terms 'free software' and 'open sources software' appear to hide completely different domains despite their massive overlap. The other domain of 'free' and 'open source' is that the domain of 'proprietary software'. The domain of the latter encloses terms like 'closed' software and 'shareware'. The existence of the 3 completely different domains of free, open source and proprietary software needs that a minimum of 2 of those domains are clearly outlined, whereas the third domain covers those software that's excluded from the others. Such a definition has been originated for 'free software' by the Free Software Foundation (FSF, www.fsf.org) and for 'open source software' by the Open Source Initiative. [3] According to the FSF, software can be labelled as free software if the associated license conditions fulfil the 'Free Software Definition', which grants four freedoms:

1. The freedom to run the program for any purpose.
2. The freedom to check how the program works and adapt it to your needs.
3. The freedom to redistribute the software.
4. The freedom to boost the program, and to unleash your enhancements to the public, in order that the total community edges.

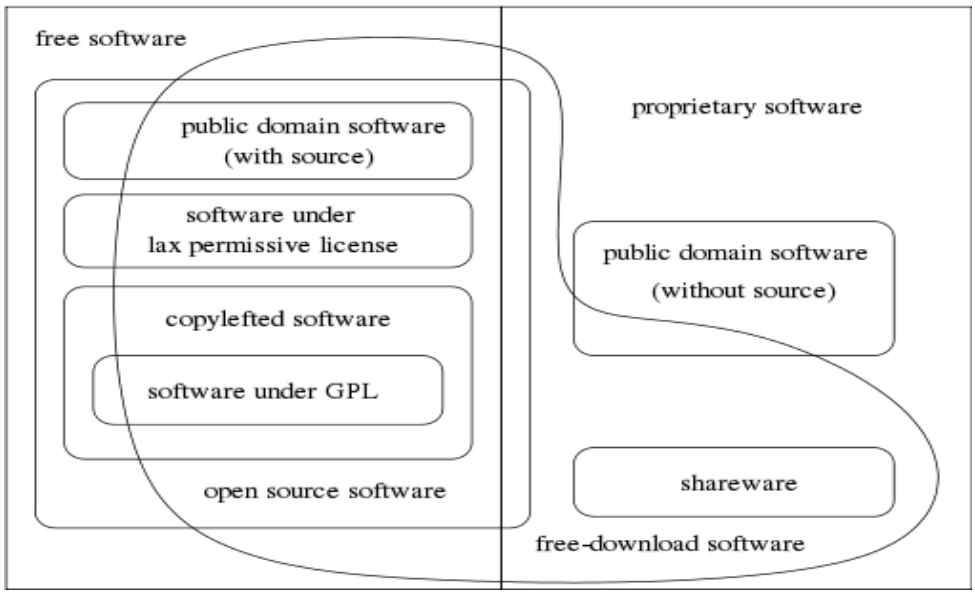

Figure 1. *Terms used with respect to software licenses. Figure from Chao-Kuei, www.fsf.org/licensing/essays/categories.html).*

When we call software "free'', we mean that it respects the users' essential freedoms: the freedom to run it, to study and change it, and to redistribute copies with or without changes. This is a matter of freedom, not price. [4]

For this reason the alternative domain to 'free software' isn't 'commercial software', wherever 'commercial' indicates that the package is oversubscribed or accustomed create a living or profit. The alternative of 'free software' is 'proprietary software', wherever 'proprietary' indicates possession.

1.2 When should we use open source software?

Both proprietary GIS software and open supply GIS software square measure equally vital for GIS education. Several GIS academics choose proprietary GIS software for GIS education as a result of students will learn the thought software skills and have blessings within the job markets. On the opposite hand, some GIS academics favor to use open source software as a result of it's freed from price and permits for the liberty to change and distribute GIS applications. This paper won't argue that direction is best for GIS education, however rather counsel once GIS academics ought to or may use open source software. According to Ming, [5] within the following things, it's going to be an honest chance to think about open supply software system in your categories:

- Teachers would like to explore the possibility of teaching GIS in a very short period, but do not have immediate financial support from schools or software vendors to purchase GIS software.
- Students would like to install and try GIS software on their home computers.
- School computers are using non-Windows operating systems, such as MacOSX or Linux.
- Teachers would love to focus on an exact side of GIS functions, like management, internet mapping, remote sensing, or spatial analysis, and that they could understand that industrial GIS packages don't offer these individual functions, or the price of adding these extra functions are too valuable.
- Teachers would love to demonstrate some distinctive GIS functions to students tomorrow. (Most business GIS software system can take over one week to nail down the licensing with vendors. you'll be able to transfer and use open source software system directly.)

III. RULES / NORMS FOR OPEN SOURCE SOFTWARE

There is delusion among varied users and developers concerning the particular which means of Open Source Software. In line with Moreno [6], deliberate the factors for Open Source Software that area unit as follows:

- **Free Redistribution:** The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale.
- **Source Code:** The program should embody source code, and should enable distribution in source code also as compiled type. wherever some sort of a product isn't distributed with source code, there should be a well-publicized suggests that of getting the source code for no over an affordable physical value ideally, downloading via the web for complimentary. The source code should be the well-liked type

during which a computer user would modify the program. Deliberately obfuscated source code isn't allowed. Intermediate forms like the output of a preprocessor or translator aren't allowed.

- **Derived Works:** The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software.
- **Integrity of the Author's Source Code:** The license may restrict source-code from being distributed in modified form only if the license allows the distribution of "patch files" with the source code for the purpose of modifying the program at build time. The license must explicitly permit distribution of software built from modified source code. The license may require derived works to carry a different name or version number from the original software.
- **No Discrimination against Persons or Groups:** The license must not discriminate against any person or group of persons.
- **No Discrimination against Fields of Endeavor:** The license must not restrict anyone from making use of the program in a specific field of endeavor. For example, it may not restrict the program from being used in a business, or from being used for genetic research.
- **Distribution of License:** The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties.
- **License Must Not Be Specific to a Product:** The rights hooked up to the program should not rely on the program's being a part of a selected software distribution. If the program is extracted from that distribution and used or distributed among the terms of the program's license, all parties to whom the program is decentralized ought to have a similar rights as people who area unit granted in conjunction with the first software distribution.
- **License Must Not Restrict Other Software:** The license must not place restrictions on other software that is distributed along with the licensed software. For example, the license must not insist that all other programs distributed on the same medium must be open-source software.
- **License Must Be Technology-Neutral:** No provision of the license may be predicated on any individual technology or style of interface.

IV. OPEN SOURCE DESKTOP GIS PROJECTS

In the following subsections, we describe some desktop GIS project in terms of its foundation, application focus, as well as its user and developer community – the detail of these descriptions is dependent on the availability of information. Critical points that are known and which are of interest from a (research) user perspective may also be mentioned.

4.1QGIS

QGIS (previously known as Quantum GIS) is a cross-platform free and open-source desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. Gary Sherman began development of Quantum GIS in early 2002, and it became an incubator project of the Open

Source Geospatial Foundation in 2007. Version 1.0 was released in January 2009. As a free software application under the GNU GPL, QGIS can be freely modified to perform different or more specialized tasks.

4.2. GRASS GIS

GRASS GIS, commonly referred to as GRASS (Geographic Resources Analysis Support System), is a free and open source Geographic Information System (GIS) software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization. The roots of the GRASS GIS project first sprouted 33 years ago. GRASS GIS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies. It is a founding member of the Open Source Geospatial Foundation (OSGeo).

4.3. uDIG

uDig is a GIS software program produced by a community led by Canadian-based consulting company Refractions Research. It is based on the Eclipse platform and features full layered Open Source GIS. It is written in Java and released under EPL and BSD licenses (formerly under GNU LGPL).

User-friendly Desktop Internet GIS (uDig) is an open source spatial data viewer/editor, with special emphasis on the OpenGIS standards for internet GIS, the Web Map Server (WMS) and Web Feature Server (WFS) standards. uDig is:

- **User-friendly,** providing a familiar graphical environment for GIS users;
- **Desktop located,** running natively on Windows, Mac OS/X and Linux;
- **Internet oriented,** consuming standard and de facto geospatial web services; and,
- **GIS ready,** providing the framework on which complex analytical capabilities can be built, and gradually subsuming those capabilities into the main application.

4.4.gvSIG Desktop

It has been founded by the Regional Council for Infrastructures and Transportation (CIT) of Valencia (Spain) to replace software of similar functionality as ESRI's ArcView in municipal authorities, since the regional government aims to switch all systems to a Linux-based computer infrastructure (gvSIG 2006, Alfaro and Rico 2005) [10]. The development of gvSIG had started at the end of 2003 and is led by the company IVER S.A. (Spain). Several universities and other companies are included in the project. gvSIG is known for its user-friendly interface and being able to access all common vector and raster formats.

4.5.OpenJUMP GIS

JUMP is a Java based vector and raster GIS and programming framework. Current development continues under the OpenJUMP name. The JUMP project was founded in 2002 by a consortium of two Canadian provincial ministries and two companies. The objective was to develop a GIS specifically for data editing and data conflation. OpenJUMP is an easy to use and powerful desktop GIS that enables users to display, edit, analyze and conflate geographic data. It comes in a CORE and a PLUS edition, with the latter adding lots of useful plugins. OpenJUMP is excellent for data editing and rapid prototyping of GIS functions.

It is platform independent (Windows, Linux, Unix, Macintosh). It reads and writes ESRI Shapefile, GML, JML, CVS, OSM, DXF and PostGIS. It also supports multiple languages.

4.6.SAGA

SAGA (System for Automated Geoscientific Analyses) is an open source geographic information system (GIS) used for editing and analyzing spatial data. It includes a large number of modules for the analysis of vector (point, line and polygon), table, and grid and image data. Among others the package includes modules for geostatistics, image classification, projections, simulation of dynamic processes (hydrology, landscape development) and terrain analysis. The functionality can be accessed through a GUI, the command line or by using the C++ API.

SAGA has been in development since 2001, and the Centre of SAGA development is located in the Institute of Geography at the University of Hamburg, with contributions from the growing worldwide community.

4.7.ILWIS – Integrated Land and Water Information System

Integrated Land and Water Information System (ILWIS) is a geographic information system (GIS) and remote sensing software for both vector and raster processing. ILWIS, like GRASS, is a mature open source GIS. ILWIS development started at the ITC, Enschede (the Netherlands) in the 1980s as proprietary software, and combines GIS functionality with image processing functionality. Thus, reported examples of ILWIS applications range from image analysis to erosion modelling. The software documentation for version 3.0 (released in 2001) is very good as it has been also used for teaching purposes at ITC and elsewhere.

Within the year of 2008, the software should be made available to end users that use operating systems other than MS-Windows, such as Linux or MacOSX.

4.8.MapWindow GIS

MapWindow GIS is an open source GIS (mapping) application and set of programmable mapping components. It has been adopted by the United States Environmental Protection Agency as the primary GIS platform for its BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) watershed analysis and modeling software.

MapWindow GIS is distributed as an open source application under the Mozilla Public License distribution license, MapWindow GIS can be reprogrammed to perform different or more specialized tasks. There are also plug-ins available to expand compatibility and functionality.

The application is built upon Microsoft .NET technology.

4.9.FalconView

FalconView is a mapping system created by the Georgia Tech Research Institute. It was initially developed for the Windows family of operating systems; however, versions for Linux and mobile operating systems are under development. It displays various types of maps and geographically referenced overlays. Many types of maps are supported, but the primary ones of interest to most users are aeronautical charts, satellite images and elevation maps. FalconView also supports a large number of overlay types that can be displayed over any map background. It supports various types of display like elevation, satellite, LiDAR, KMZ and MrSID.

4.10.TerraView

TerraView is a GIS application built on the TerraLib GIS library. TerraView handles vector data (polygons, lines, points) and raster data (grids and images), both of them stored in a relational or geo-relational database,

including ACCESS, PostgreSQL, MySQL and Oracle Spatial. TerraView has a visualization interface that allows attribute and spatial queries on object in geographical database. The interface allows different views on the database, producing thematic maps with different types of legends.

TerraView is able to manage raster data in geographical database and allows the visualization and manipulation of raster data together with vector data. Raster data can be shared in different formats such as GeoTIFF, TIFF, JPEG, RAW, ASCII-Grid or ASCIISpring.

We've studied many published papers and various books after which we created the following table with our findings. Maurya [7] listed several open source GIS software which is presented here in the extended form in Table 1 with details:

GIS Software (Released on)	Developers/ Developed by	Used in application(s)	Development Platform/ Language support	Software License	Website
QGIS (July 2002)	QGIS Development Team	Viewing, Editing, Analysis, Grass-GUI, SAGA-GUI	C+ +, Qt4, Python	GPL	http:/qgis.org/en/site
GRASS (1982)	GRASS Development Team	Analysis and scientific visualization, cartography, modeling and simulation	GNU/Linux, Mac OSX, MS Windows	GPL	http://grass.osgeo.org
uDIG (2004)	Refractions Research	Viewing, Editing, Analysis	Windows, Linux, Mac	Dual BSD / EPL (Eclipse Foundation)	http://udig.refractions.net/
gvSIG Desktop (2003)	gvSIG Association	Viewing, Editing, Analysis (Mobile Applications)	Windows, Linux	GPL	http://www.gvsig.com/

OpenJUMP GIS (2002)	Company, government	Viewing, Editing, Analysis	JAVA	GPL	http://www.openjump.org
SAGA (2001)	Universities	Analysis, modeling, scientific visualization	C+ + (MS Visual C+ +)	LGPL (API), GPL	http://www.saga-gis.org
ILWIS (1985)	52°North ILWIS Community	(Raster) Analysis	(Raster) Analysis	GPL	http://52north.org
MapWindow GIS (1998)	MapWindow Open Source Team	Providing core GIS and GUI functions, developing decision support systems	MS Visual Studio.NET (C+ +, C#, VB.NET)	MPL	http://www.mapwindow.org
FalconView (1994)	Georgia Tech Research Institute	Map display, Overlay analysis	JAVA	LGPL	http://www.falconview.org
TerraView (2001)	Brazilian National Institute for SpaceResearch (INPE)	Vector and Raster analysis, Statistical analysis	C++, R	GPL	http://dpi.inpe.br/terralib5 /wiki/doku.php

Table 1: *Detailed view different Open Source Software*

4.11.COMPARISON OF OPEN SOURCE SOFTWARE WITH PROPRIETARY SOFTWARE

As per the Maurya [7], there are many open source GIS software are available but QGIS is most popular among them. ArcGIS is most popular proprietary software in the field of GIS so at few places we try to compare it with QGIS.

Too Many Projects: There are many open source projects for every niche, and you'll have to spend some time picking the best one, because other will be abandoned.

User platform: Most of the users, and many developers, will consider this as an advantage. Windows Open Source software tools have gone a long way in the past years, but the best-of-breed software is almost always in the Linux world. Whereas ArcGIS is MS-Windows based software.

Documentation: Documentation is superb in ArcGIS. QGIS has lots of documentation; well written. There are numerous tutorials you can download and try for yourself. There are excellent introduction videos. QGIS does not lack documentation at all.

Support: If you're going to pay for it, you'll probably get good telephone support from the vendor.

Whereas in open source probably no tech support or SLA, unless you pay a consultant.

Cost: With proprietary software, when you need an extra software component that would fit to your existing infrastructure, it's probably going to cost you a lot more.

Effort: Open source software is, almost by definition, more flexible but requires more effort to use, whereas the opposite is true for proprietary software in general.

Performance: QGIS is somehow faster than ArcGIS for most operations considering QGIS' newer architecture and code base it's not difficult to understand why it is faster.(it's often difficult to improve performance of a large codebase application without using new technologies). QGIS is much faster working with PostGIS than ArcGIS, unless you opt-out and store your data in PostgreSQL using

ESRI's own spatial format.

Availability of tools: QGIS does have less available operations and algorithms than ArcGIS, mainly if you consider advanced ArcGIS Extensions like 3D Analyst, Geostatistical and Network i.e. QGIS just support Dijkstra's algorithm for solving network problems while ArcGIS extends it and solve more network problems.

License: This is a huge advantage that open source software can be licensed and can be distributed whereas proprietary software can't be distributed.

Completeness: ArcGIS is a set of products that obviously work very well together. QGIS was born to work with PostGIS. There is also a set of products similar to ESRI's that pack QGIS as the desktop component.

Operating system dependency: Although Open Source software tools have gone a long way with Windows in the past years, but the best-of-breed software is almost always in the Linux world. Migliaccio et al. (2007) [8] experimentally prove it for the case study of CO emission under INTERMEDE BBSO project, it is observed that results generated with GRASS under Linux environment were better. Thus, there is reinforcement of the belief that free/open source GIS software is most effective and displays the maximum of its capabilities when running in a UNIX or Linux environment.

Many of the FOSS GIS applications, uDig particularly, are designed to figure with geodatabases like PostGIS, wherever geographic information and attribute tables may be hold on along and information operations like table joins will simply be accomplished. However, these geodatabases are server primarily based and don't seem to be a perfect resolution for desktop users. Not like ArcGIS, FOSS GIS presently doesn't support an easy desktop geodatabase which will be directly accessed, though SQLite may be a future candidate and is supported by GRASS and also the GDAL/OGR tools.

There are some compelling reasons to think about FOSS on the far side practicality. ArcGIS and different proprietary code is expensive for establishments and is financially preventative for many students, whereas open source software is free. Once put in during a schoolroom or workplace atmosphere, ArcGIS is often put in so it points to a license server which provides the code permission to open once launched. This limits installation to machines hardwired to the field network and needs the setup and maintenance of a zealous license server. FOSS GIS will be put in on any machine, mounted or wireless, and doesn't have a proprietary license. Presently ArcGIS solely runs on Windows, whereas most FOSS GIS applications area unit cross-platform.

Despite the benefits of FOSS GIS, it might seemingly be associate degree addition to the GIS toolkit for giant analysis libraries and not a replacement for proprietary GIS product. Libraries with GIS services can still have to be compelled to offer ArcGIS to meet the requirements of their patrons. Documentation, support, and coaching for ArcGIS, MapINFO, and different product still outstrips that of the FOSS alternatives. ESRI additionally provides instructional materials like its virtual field courses and temporary free or low price package to students to beat a number of the value problems.

V. STRENGTHS AND WEAKNESSES OF OPEN SOURCE AND PROPRIETARY GIS SOFTWARE

In the following section, as per WEIS [9] and our findings, we aim to discuss the advantages and disadvantages of FOSS GIS in comparison to proprietary products from a general perspective.

5.1. Open Source GIS Infrastructure

Pros

- **Community support -** Perhaps the best FOSS advantage. There is just about absolute confidence relating to a well-liked open source project that haven't got a profound answer within the internet. For the undocumented queries, you will likely get a solution inside twenty four hours in a very skilled forum.
- **Scalability -** If you are using Open Source software, you can switch over to a more powerful server or add a second server behind a load balancer. If you are paying licenses based on the number of cores or the number of users hitting the app, you are looking at a significant increase in license costs.
- **Trying before implementing -** If you want to convert a software component to a different infrastructure, technology or environment, you can have a free sandbox to play with before converting, and you can always go back. This allows priceless experience with cutting-edge technologies without the financial risks involved with trying new pricy products.
- **Great web tools -** There's a plethora of web-oriented open source tools: mapping, tiles, databases, webservers, web framework and web authoring tools. Building your first GIS website will be very easy.
- No license fees.
- Unrestricted use (e.g., no limits for the number of installations).
- No update enforcement.

- Support of open standards.
- Support usually available from several providers.
- Customization at API level and below.

Cons

- **Probably no tech support or SLA -** Unless you pay a GIS consultant.
- **GUI tools are of inferior quality -** This is probably because software developers are familiar with command-line tools, and there are not enough open source GUI designers. The resulting GUI (e.g., GRASS GIS) is often slow, ugly, and have counterintuitive interface.
- **Mostly Linux based software -** Windows Open Source software tools have gone a long way in the past years, but the best-of-breed software is almost always in the Linux world.
- **GPL \ License restrictions -** This is hardly a con, because proprietary software can't be distributed at all. But note that in most cases, modifying and distributing Open Source product forces you to redistribute the new source code.
- Installation know-how necessary.
- Training costs.

5.2. Proprietary GIS Infrastructure

Pros

- **ProArcGIS - De Facto standard -** ArcGIS, the most popular non-free GIS infrastructure, tend to be an industry standard. It's not the only standard there is, and there are many conversion tools, by most of your clients ask for data that can be opened with ArcGIS tools.
- **Better GUI -** Nearly always.
- **MS-Windows friendly -** Most of the users, and many developers, will consider this as an advantage.
- **Support -** If you're going to pay for it, you'll probably get good telephone support from the vendor.
- Warranty of developing company on product (holds for every company).
- Components should work together.
- Usually well documented software.

Cons

- **Cost tend to pile up -** When you need an extra software component that would fit to your existing infrastructure, it's probably going to cost you a lot more.
- Software price and maintenance fees.
- Training costs.
- Maintenance tied to specific licensed companies.
- Customized development can be difficult due to available resources of vendors.
- Support only as long as Software Company exists.

VI.CONCLUSION

Over the past few years, the demand for GIS and location analytics has intensified. Every day, more people rely on maps and insights to find prospects, enhance networks and manage risk. To meet this demand, you need to access more data, enrich every insight and find the right answer fast, capabilities you'll get with either open source or proprietary GIS systems. To develop GIS, a number of software tools and packages are available. We think that the most effective GIS software system is that the one that everyone will use simply. Not a lot of learning curve needed for it. If you have got slightly background in GIS then the merchandise ought to be usable straightaway to you. In this paper, we concluded that the idea that proprietary and open source solutions are polar opposites is certainly not true. Although many of the characteristics of open source versus proprietary software packages clearly set them far apart, they also share several features too. Software vendors have built proprietary solutions that they have later released as open source. Similarly, there are distributors of license-free, open source packages who also offer a for-profit, licensed and proprietary version built upon the original open source platform. It is really difficult to decide without qualifications which model is the best software development model for your organization to adopt: open source or proprietary.

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