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Empirical Study on Spreadsheet Quality: Case of Serbian SMEs

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Abstract
This paper presents the results of a research which involved analysis of spreadsheets collected from 40 Serbian SMEs. Based on related research, the collected spreadsheets were analysed for presence of errors and assessed in terms of quality criteria, defined in line with the literature review. The final results are consistent with related research and point to various aspects of spreadsheet use that should be improved by the respondents for the purpose of reducing risk associated with development and use of spreadsheets.

Keywords
spreadsheet errors, spreadsheet quality, error-rate

Introduction

Spreadsheets are amongst most frequently used commercial software by a majority of organizations. Records, reports, charts, various analyses used in operations and decision making are most likely to be developed or adapted using a spreadsheet software. The fact that export into Excel files has become a standard feature of business software has only contributed to the popularity of spreadsheets.

Owing to a fast learning curve of wide range of functionality, an average user quickly becomes adept at using spreadsheets. However, due to their ease of use, careless users are usually unaware of error-proneness of different spreadsheet applications. The records on negative consequences of inappropriate development and use of spreadsheets have grown immensely over the last years ("The European Spreadsheet Risks Interest Group," n.d.).

This paper provides an overview of a subset of results from a more comprehensive research on spreadsheet use. Operational spreadsheets gathered form Serbian SMEs were analysed with the intent to estimate the degree to which they comply with the defined quality criteria and test the claim prevalent in related research on the discrepancy between the actual proportion of spreadsheets containing errors and the end users' estimates of this proportion. After a literature review, based primarily on a previous research by Raković (2014), the paper continues with research results, followed by concluding remarks.

1. Literature review

The proportion of human error is similar among different areas of human activities. Panko (2007) presented the data on the degree of accuracy of mechanical, simple tasks, as well as more complex actions in text editing, programming and spreadsheet development (Table 1). When it

comes to mechanical actions (data entry or cell selection), the degree of accuracy of text, program code and spreadsheets ranges between 99.5% to 99.8%. However, with formulas (that is, more complex actions), this degree drops by several percent. In Table 1, presenting Panko's results, complex thought is signified with C, whereas a greater number of complex thoughts is designated as "the product", and signified with C^n. At the level of a more complicated document, program, worksheet or workbook, the degree of accuracy declines to a 0%. In other words, more complex texts, programmes and spreadsheets will, most certainly, contain errors.

Table 1. Comparrison of accuracy in spreadsheet editing, development, and programming

	Text editing	Programming	Spreadsheet	Accuracy
Mechanical action	Text input Spelling	Code editing Parentheses	Input Cell selection	99,5% - 99,8%
Complex thought (C)	Grammar Meaning	Statement Code line	Formula	95% - 98%
Product (C^n)	Document	Program module	Spreadsheet module	0%

Source: Panko, 2007

In a 2013 paper, Panko and Port (R. R. Panko & Port, 2013) systematised the results of studies concerned with spreadsheet errors conducted after 1995 they deemed most significant. Their results are presented in Table 2.

Table 2. Spreadsheet-related studies

Authors	Number of spreadsheets analysed	Percentage of Spreadsheet Models Containing Errors
Hicks (1995)	1	100%
Coopers & Lybrand (1997)	23	91%
KPMG (1998)	22	91%
Lukasic (1998)	2	100%
Butler (2000)	7	86%
Clemont, Hanin i Mattermeler (2002)	3	100%
Lawrence and Lee (2001)	30	100%
Powell, Baker and Lawson (2009a)	50	86%
Powell, Baker and Lawson (2009b)	25	44%
Average after 1995	163	84%

Source: adapted from: Panko & Port, 2013

With the intent to achieve a greater quality of description of errors present in spreadsheets, Panko and Halverson (R. Panko & Halverson, 1996) proposed new indicators to complement the Percentage of Spreadsheet Models Containing Errors—Number of Errors per Model and Error Magnitude (indicates how the error affects the model outputs). However, the proposed indicators did not become widely accepted, which is why the authors later introduced the term Cell Error Rate (CER), based on a programming concept of Fault per thousand lines of (noncomment) source code (fault/KLOC). Almost 15 years after its introduction, Panko and Aurigemma (2010) realised that the term was used ambiguously among researchers, which rendered comparison impossible. While some researchers compared the number of errors with a total number of cells containing formulas, others used the total number of filled-in cells as the denominator. Therefore, Panko and Aurigemma (2010) defined 5 quantifiers of erroneous cells (Table 4), based on the type of cell content:

1. numbers and formulas (Cell Error Rate Value cells - CERV)
2. solely formulas (Cell Error Rate Formula cells - CERF)
3. solely numbers (Cell Error Rate Number cells - CERN)
4. solely text (Cell Error Rate Text cells - CERT) or
5. taking in consideration all nonempty cells (Cell Error Rate Value All nonempty cells - CERA)

Table 4. Different quantifiers of erroneous cells

Acronym	Denominator	Use
CERV	Value cells (cells containing numbers or formulas)	Indicator of the proportion of erroneous cells containing numbers and formulas, excluding text. CERV is identical to the previously introduced CER.
CERF	Formula cells	Focuses on the proportion of erroneous formula cells, which is generally higher than CERV.
CERN	Number cells	Indicator of errors in content entry.

CERT	Text cells	Indicator of errors in labelling and documentation.
CERA	All nonempty cells	Several studies use this indicator as well, although it is not considered useful enough.

Source: Panko & Aurigemma, 2010

In the research concerned with the percentage of erroneous cells revived by R. Panko (2005), CERF ranged from 4.3% to 21.0%, while CERV ranged from 1.1% to 11.9%.

The risk of spreadsheet errors is closely related to their creators' overconfidence, which is a manifestation of the gap between their self-perceived and actual knowledge and skills (M. Grant, D. Malloy, & C. Murphy, 2009; Takaki, 2005). Inadvertence of errors was corroborated by results of several studies (Caulkins, Morrison, & Weidemann, 2008; R. Panko, 1998). Panko (2009) reports that errors were discovered in spreadsheets developed by 86% respondents, whereas only 18% of respondents expected their spreadsheets to contain errors.

Reaction in occurrence of errors and minimisation of other risks associated with the use of spreadsheets is the primary focus of frameworks for spreadsheet development and use. Based on research on spreadsheet errors, inferred guidelines, positive experiences, and best practices in spreadsheet development (Baker, Powell, Lawson, & Foster-Johnson, 2006; Bewig, 2005; Colver, 2010; Dunn, 2010; Ferreira & Visser, 2012; Grossman & Özlük, 2004; Kulesz & Zitzelsberger, 2012; Powell, Baker, & Lawson, 2008b, 2008a; Powell, Baker, Lawson, McDaid, & Rust, 2009; Read & Batson, 1999; Weber, 2006), as well own research results (Rakovic, 2014), Rakovic (Raković, 2014; 2019) developed a framework for spreadsheet development and use (Figure 1). Guidelines for the design, implementation and documentation phases proposed by the framework were used as a basis for defining criteria for assessment of collected spreadsheets, results of which are presented in the next chapter. With its particular emphasis on the significance of spreadsheet documentation, the aforementioned framework suggests that each spreadsheet contains an additional worksheet titled "Documentation", with the following information:

- A brief description of the purpose of the spreadsheet
- Description and specification of all inputs (units of measurement and the range of values for each individual cell)
- Specification of all formulas
- Data on the developer: full name, organisational unit, contact information (email, telephone)
- Data on the responsible person
- Creation date
- Records on modifications (with dates and descriptions)
- Records on verification, person that verified the spreadsheet, verification date
- Instructions for use

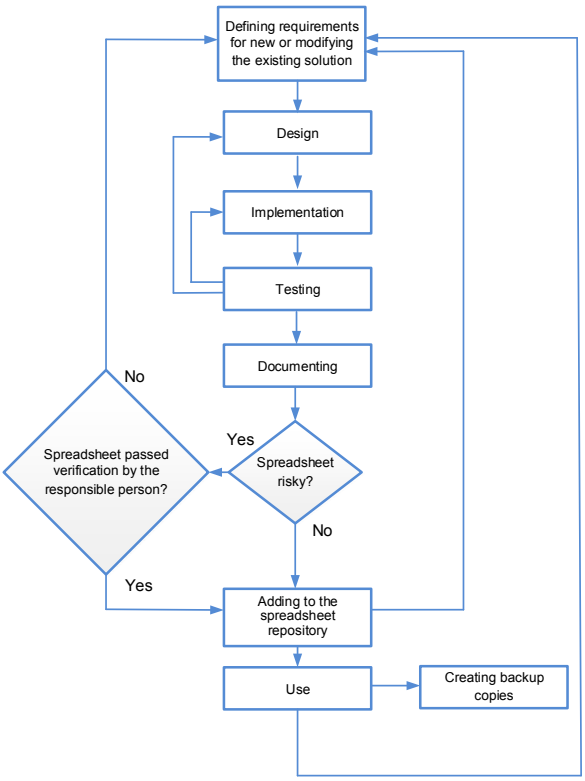

Figure 1. Framework for spreadsheet end-user development
Source: Raković, 2014; 2019

2. Research results

A total of 40 spreadsheets were collected from micro, small and medium Serbian businesses. The collected spreadsheets were not specially developed for this research, but rather operational, used by the respondents in their everyday tasks. The spreadsheets were not trivial, but at a sufficient level of complexity to be considered a Product (C^n), referenced in Table 1.

Each respondent also submitted a questionnaire which, among other things, served

to gather the information whether the respondent expected errors to be discovered in their spreadsheets. 90% of respondents expected their spreadsheets to be free of errors.

The following criteria for spreadsheet assessment were defined, in line with the framework proposed by Raković (2014):

Crit1 Adherence to a predefined convention for naming workbooks, worksheets, cell labels, cells, and ranges
Crit2 Use of descriptive, suggestive workbook names
Crit3 Use of descriptive, suggestive worksheet names
Crit4 Use of descriptive, suggestive cell names
Crit5 Use of descriptive, suggestive range names
Crit6 Workbook password protection
Crit7 Worksheets password protection
Crit8 Presence of table heading rows
Crit9 Separation of inputs, calculations, and outputs
Crit10 Different background colouring of cells containing inputs, calculations, and outputs
Crit11 Existence of data validation rules in input cells
Crit12 Use of conditional formatting
Crit13 More frequently used input cells clearly different from other input cells
Crit14 Simplicity of formulas
Crit15 Constants in special cells
Crit16 Dependent formulas positioned as close as possible
Crit17 Formula arguments positioned above and/or left from the formula
Crit18 Use of formula protection feature against inadvertent changes

Analysis of "physical" characteristics of collected spreadsheets indicated that the majority of workbooks contained no more than 3 worksheets (Figure 2), up to 1000 filled-in cells (Figure 3), and up to 100 unique formulas (Figure 4).

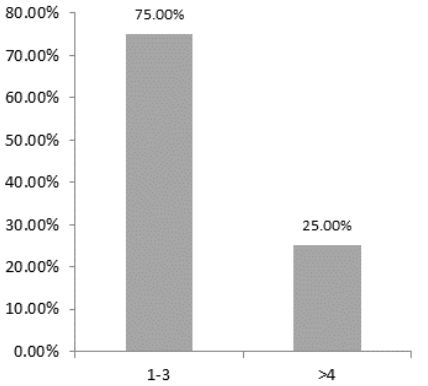

Figure 2. Number of worksheets in a workbook
Source: Authors.

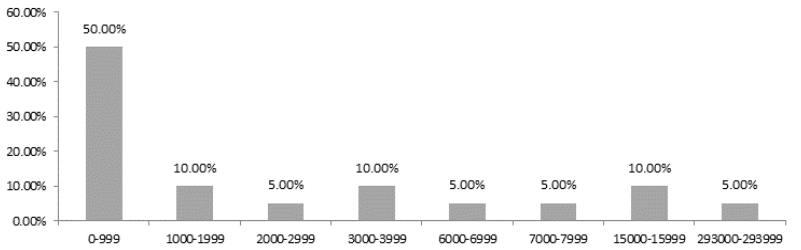

Figure 3. Number of filled-in cells in a workbook
Source: Authors.

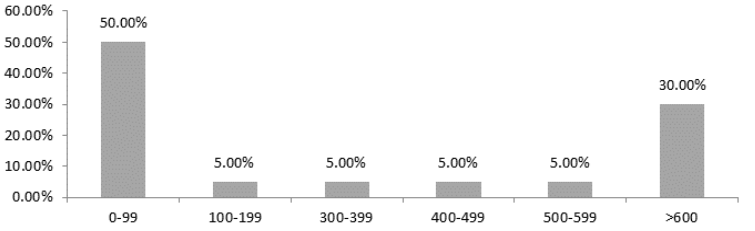

Figure 4. Number of unique formulas in a workbook
Source: Authors.

The proportion of compliance with criterial 1 through 18, expressed in percents, is presented in Figure 5.

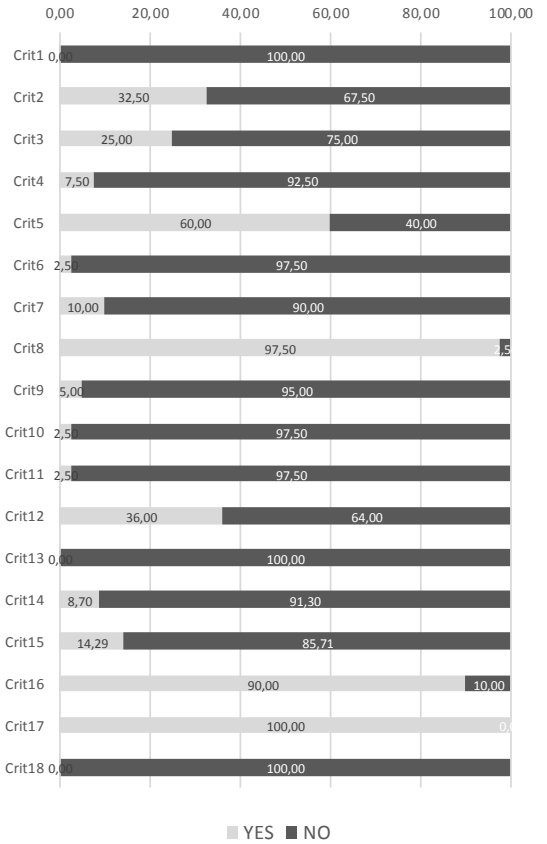

Figure 5. Proportion of compliance with criterial 1-18
Source: Authors.

Note: Compliance with criteria Crit 5 and Crit 13 could be tested on only 5 spreadsheets, while compliance with Crit12, Crit14 i Crit15 could be tested on 25, 23, and 14 spreadsheets, respectively.

Formula arguments were positioned above and/or left from the formula in all analysed spreadsheets (Crit 17). Criteria with a high degree of compliance also included Crit 8–Presence of table heading rows (97.5%) and Crit 16–Dependent formulas positioned as close as possible (90%). Ranges were named in three out of five spreadsheets they were used in (Crit 5, 60%).

Results indicated a complete lack of predefined convention for naming workbooks, worksheets, cell labels, cells, and ranges (Crit 1), visual distinction of frequently used input cells (Crit 13) and formula protection (Crit 18). Majority of analysed spreadsheets did not employ suggestive, descriptive cell names (Crit 4, 92.5%), separation of inputs, calculations, and outputs (Crit 9, 95%) and visual distinction (Crit 10, 97.5%) of input, calculation, and output cells, data validation (Crit 11, 97.5%), formula simplicity (Crit 14, 91.3%) and separation of constants into special cells (Crit 15, 85.71%). Only 32.5% of analysed workbooks and 25% of worksheets had descriptive, suggestive names (Crit 2 and Crit 3), while out of 25 spreadsheets where it was deemed meaningful to use conditional formatting, only 9 employed this feature (Crit12, 36%).

None of the analysed spreadsheets contained any form of documentation.

85% of analysed spreadsheets contained errors, with the total number of errors varying from 1 to 3650 (original and copied errors). The following errors were detected: use of constants in formulas, references to a non-existent cell, division by zero, use of text as formula argument, errors in VLOOKUP function arguments, and references to workbooks not supplied. The proportion of erroneous cells to all nonempty cells (CERA) was 2.18%, to cells containing numbers and formulas (CERV) was 3.12%, while the proportion of erroneous cells to a total of cells containing formulas (CERF) was 7.25%. It was not possible to compute CERN and CERT.

Conclusion

The research results show similarity with a number of related studies. The proportion of spreadsheets containing errors in total analysed spreadsheets (85%) is close to the average value among related researches (84%), while computed values of CERF (7.25%) and CERV (3.12%) are lean towards the lower brackets of reference ranges (CERF: 4.3%–21%, CERV: 1.1%–11.9%).

According to questionnaire data, only 10% of the respondents acknowledged the possibility of their spreadsheets containing errors. The discrepancy between their estimates and the actual number of spreadsheets containing errors (85%) points to overconfidence among the respondents.

Assessment of quality of analysed spreadsheets clearly suggests that frameworks and best practices are not employed to guide correct development and to ease the use of spreadsheets, and in turn reduce spreadsheet-related risks. On average, analysed spreadsheets received positive

assessment in only 4 out of 18 criteria. The greatest reason for concern is the prevalence of negative assessments in relation to criteria directly linked to spreadsheet errors and spreadsheet-related risks: non-use of data validation, complex formulas, use of constants in formulas, unprotected formulas, worksheets, workbooks, etc.SM

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