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RESEARCH ON THE EFFECTIVENESS OF THE MANAGEMENT OF THE DIRECTION / PUBLIC SERVICE OF TAXES AND LOCAL TAXES ON THE REFORM OF THE PUBLIC ADMINISTRATION

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Abstract

In the last three decades, we have witnessed a series of reforms regarding the management of the public sector and the efficiency of its activity to respond as adequately as possible to the needs or demands of citizens. The governments, through the reform proposals, wanted to improve the efficiency and effectiveness of the public sector, the implementation of solid and stable administrative practices, the development of organizational management and strategic management regarding fiscal activity, fiscal compliance, collection of taxes and fees, risks regarding non-compliance with budgetary obligations.

Through this paper, we wanted to analyze the tax reform and public administration reform, the perception of fiscal-budgetary policy by taxpayers, the relationship between local tax administration and taxpayer, the quality of the management of the tax institution reflected in the relationship between managing civil servant and executive civil servant, but also in the relationship with the citizen, the satisfaction and motivation of work in the case of civil servants, the impact of computerization on taxpayers and the activity of civil servants.

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Key words: Management effectiveness; taxes; local taxes; public administration

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1. Introduction

Taxation or the system of taxes and fees appeared with the formation of human communities, the idea of collectivity and collective necessity, or what we now call service of public interest. The main objective of tax administrations has always been to optimize the collection of taxes and fees and the level of tax compliance.

The management of the organization, the organizational climate, the quality of the tax administration-citizen relationship, the behavior of taxpayers in terms of tax compliance or non-compliance, insufficient information about the nature, role, and impact of taxes and local taxes, the complexity of tax procedures, are aspects that reflect on the efficiency and the effectiveness of fiscal strategies implemented by fiscal authorities.

The efficiency of the organizational management of local tax and fee services is a necessity resulting from the need to rethink the way the local public sector operates and reform the administration. The role of organizational culture and structure, the use of information technology, managerial style and the valuing of human resources is decisive. In a dynamic environment, the tax organization must be as responsive as possible to any event that could influence its strategic direction or compromise the achievement of the set objectives. There are two starting points of this process, if we can write it like this: at the level of officials and at the level of citizens, because we consider it necessary to have a global vision that includes the objectives of the tax institution and the situation of taxpayers.

The current system of Romanian public administration has seen several reform processes, stages, and programs. I emphasize that reform does not mean only change. Reform means growth, efficiency, simplification by setting goals and achieving positive results. Simplification becomes visible when it is put into practice, both for officials and tax-paying citizens, in clear guidelines, coherent, practical and practicable public actions, in appropriate methodologies and procedures. We are talking in parallel about a management of reform and a management of change aimed at meeting the demands and needs of society, but also about the need for reform within the public institution and in the relationship with the public, a recipient too often neglected or forgotten. The socio-economic conditions, the management of the emerging crises, the way in which the strategies were designed or chosen, along with the quality and professional capacity of those involved in the reform process, influenced its success, uncertainty or failure.

A well-thought-out reform process means holding managers and officials accountable for achieving the objectives set by public policies, and an achieved objective proves its socio-economic efficiency.

Through this paper, we wanted to research, describe and explain based on questionnaires applied to both taxpayers and civil servants working in the local taxes and fees services some aspects such as: the reform of fiscal and public administration, the perception of fiscal-budgetary policy by taxpayers, the relationship between local fiscal administration and taxpayer, the quality of the management of the fiscal institution reflected in the relationship between the leading civil servant and the executive civil servant, but also in the relationship with the citizen, the satisfaction and motivation of workers in the case of civil servants, the impact of computerization on taxpayers and the work of civil

Whether we are talking about public administration reform or management reforms, we have a common denominator: the performance of public institutions. We cannot talk about the efficiency of the management of the public service of local taxes and fees without prioritizing the relationship between taxpayers and the tax institution. The coordination of fiscal activity with the interests of the community will be directly reflected in the proper targeting and adaptation of the public service to the user. We believe that the efficiency of the provision of public services in the absence of considering the citizen-taxpayer as a partner in this relationship is directly compromised.

2. Hypotheses and research methodology

J. Steven Ott et al. (1991) defined public management as the science and art through which public administration programs are grounded, organized, and coordinated in processes of managing budgetary resources and human resources. The modernization of the public system requires the introduction of methods specific to the private sector; increasing the degree of efficiency and effectiveness is possible by creating a flexible system, oriented to the citizen, perceived as a consumer (Bartoli and Blatrix, 2022). The taxpayer citizen is introduced into this public management equation, thus creating a balance between actions and results, between the strategic-financial function and budget transparency.

Meeting the needs of citizens and public consultations send internal communication to the external environment, and creates relations between public administration and civil society. At the objective level, we can note not a reform but a succession of reforms with the aim of improving the activity of public services. What exactly the over-reformed management lacks and does not rise to the desired level remains a problem that we wanted to delve.

Although cleary oriented towards forecasting, coordination, control, and evaluation, the management lacks expected results. The new public management and the new public service are incomplete without considering the customer of these services - the citizen, his action and expectations as a taxpayer (Rhys and Van de Wall, 2013). The public administration reform strategy focused on the civil servant, his activity and his position in the system. We believe that not the civil servant but the triad taxpayer - civil servant - public institution should be brought to the center of the administrative activity regardless of the level, and taking this aspect into account would have brought the reform of the public administration to another level.

The local aspect of public administration and services emerged as a result of the decentralization process, from the need to create balance and proximity of the state to the citizen. Approaching is not possible without understanding their needs, without mutual understanding. The institution / public service-citizen partnership is the optimal solution for meeting the objectives of socio-economic and territorial development. The transfer of competences from the central level to the local level is the guarantee of citizens' participation in the decision-making process. The question is to what extent this has been achieved and whether there are sufficient credible reserves whereby the current management of local taxes and fees services ensures efficiency, balance and transparency in the management of human and material resources alongside the existence of a real partnership with the tax-paying citizen . To study these aspects, we formulated the following hypothesis:

H1: The efficient management of the direction / public service of local taxes and fees is the result of the achieved objectives of the public administration reform.

For the aspects to be studied, a series of independent variables were established: gender (male/female), place of residence (rural / urban), quality of respondents (natural persons / legal persons), level of education (high school / secondary / university) and a series of dependent variables – level of trust, degree of satisfaction, frequency of ICT use, degree of motivation, level of management quality, organizational climate, degree of achievement of objectives.

The research population is made up of employees of the local taxes and fees departments/services and natural and legal person taxpayers.

The sample is represented by 124 civil servants and 300 taxpayers from 32 of the country's 40 counties. The samples were chosen randomly by calculating the weights according to the eight development regions of Romania, the environment of residence, gender, education, seniority in the system and the position held.

At the moment of completing the questionnaires, 14.52% of the official respondents held management positions and 85.48% executive positions.

From the point of view of education, 21.77% have secondary education, 78.23% higher education, and in terms of seniority, according to the figure below, the largest share is held by civil servants with over 20 years in the system (26.61%), followed by employees with experience between 3-5 years (25.58%), 20.97% between 10-15 years, and 15.32% have experience between 6-10 years and are considered a representative lot for the problems under research.

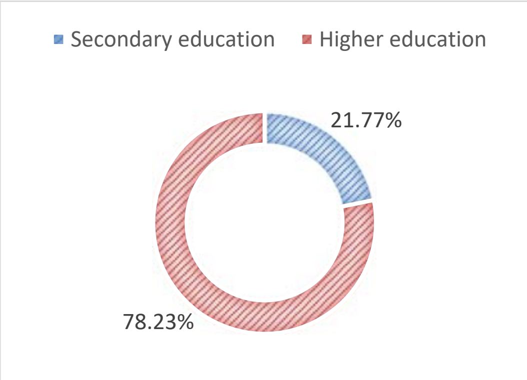

Figure 1. Education level of public servants participating in the research

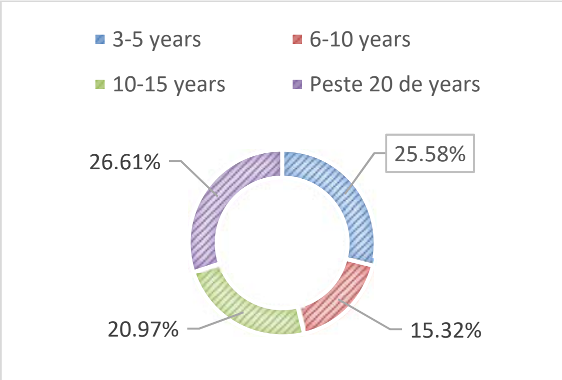

Figure 2. Seniority in the system of civil servants participating in the research

In terms of gender, 38.87% are male, 66.13% are female and come from rural areas, 17.74%, and 82.26% work in urban areas.

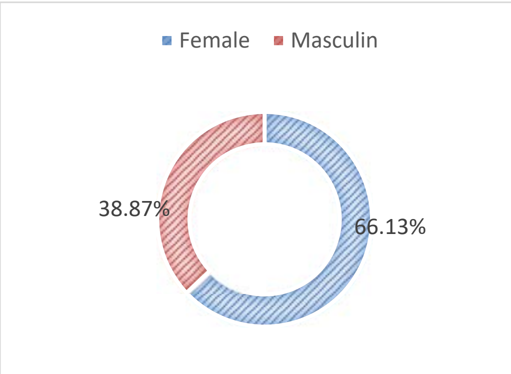

Figure 3. The gender of public servant subjects participating in the research

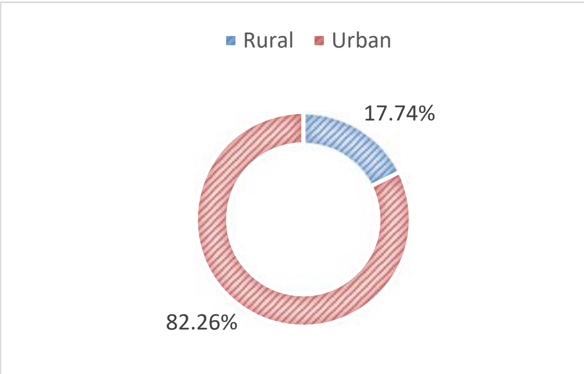

Figure 4. The residence environment of the public servants participating in the research

The group of taxpayers is made up of 88.67% individuals and 11.33% legal persons. 75.67% come from the urban environment and the remaining 24.33% from the rural environment.

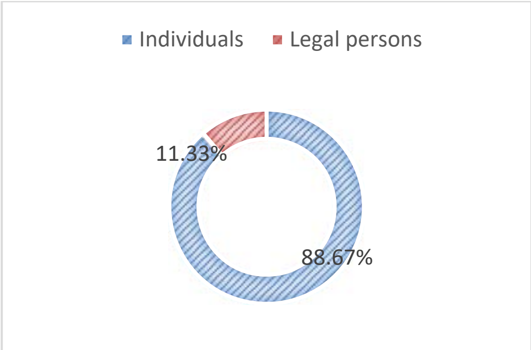

Figure 5. Type of taxpayers participating in the research

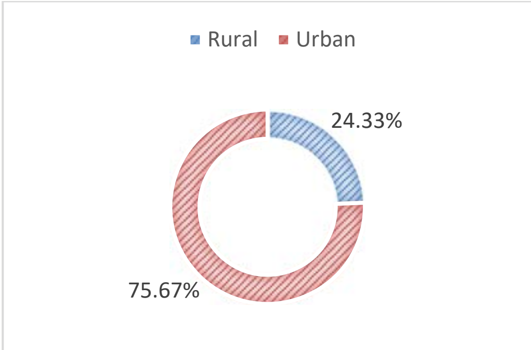

Figure 6. Residence environment of taxpayers participating in the research

As for gender, 35% are male, 65% female, and the last school completed is the gymnasium (4.33%), high school (35.33%), the rest of the respondents have either university education (46.67%) or postgraduate (13.67%).

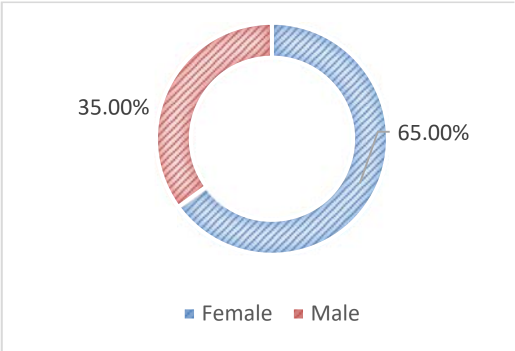

Figure 7. Gender of taxpayers participating in the research

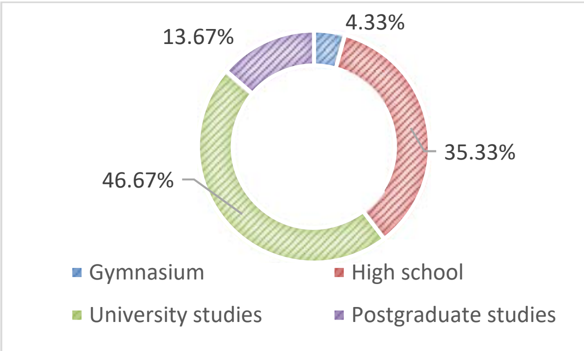

Figure 8. Education level of taxpayers participating in the research

It is considered a balanced and representative sample, a mention also valid for the period of collaboration with the direction/service of taxes and local taxes, because a long period of collaboration creates the premise of adequate responses to requests.

We mention that almost half of the respondents have been using local taxes and fees public services for over 20 years (47.33%). The lowest percentage is of taxpayer respondents who address the services in question for a period between 1 and 5 years (9.33%); for the rest of the subjects, the following situations were identified: between 6-10 years - 12.67%, 11-15 years - 14%, and for the period 16-20 years - 16.67%.

We have a balanced representation of the main categories of subjects in terms of gender, age categories, the environment of origin, the period of collaboration with the tax and local tax services.

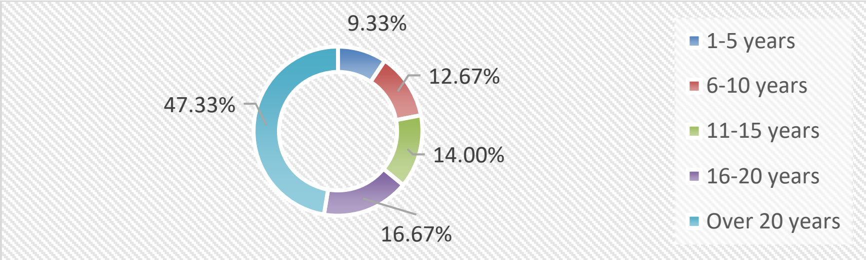

Figure 9. Taxpayers' collaboration period with the local taxes and fees service

Depending on the operational objectives of the research and the proposed dimensions, we created two questionnaires, one for each group of respondents: civil servants, respectively taxpayers.

Before the actual investigation (March-April 2021 period), the pilot investigation (January-February 2021) was conducted. In the pilot survey, the questionnaires were pretested on a sample of 50 taxpayers and 20 civil servants in an online system. At the end of the pilot research, based on the analysis and centralization of the answers, we modified, adapted and finalized the questionnaire used in the final research, we coded the answers to be later quantitatively processed in the form of percentages and averages relevant for the purpose of the research and facilitating comparisons and correlations both between the questions of the questionnaires and between the two types of questionnaires because some items are common.

The final questionnaires were applied mainly online to civil servants as self-addressed questionnaires (70% online, 30% in pencil-paper format); for taxpayers, given the pandemic context, we used a triple method of application - online, by phone, and directly in the counties near the city of Bucharest, namely Ialomița, Ilfov, Călăraşi, Brăila, Giurgiu, Bucharest.

The total number of items was 25 for taxpayers, the last two being identification questions, and 21 for civil servants. We used introductory, opinion, and control questions to check the accuracy of the answers. Some generated a single variable, because Iasked respondents for a single answer, others asked / allowed multiple choices.

We used both closed and open questions to allow respondents to formulate their own answers. For the closed questions we used several types of scales: ordinal and nominal, asking the subjects to express their agreement or disagreement in relation to the statements in the content of the item on evaluation scales from total agreement to total disagreement or to a very high degree to a very small extent.

The questionnaire has closed questions with single answer or multiple answer, matrix questions with single answer and open questions with free answer. The response time was reasonable, there were no comments from the respondents related to the number of questions or the time to complete.

The data processed following the application of the two questionnaires were centralized in Excel to create an SPSS database. The Bravais Pearson correlation coefficient was determined for variables defined in the items specific to the organizational management of local tax and tax services.

The processing of the series through the SPSS program as well as the parallel interpretation of the answers provided by the two groups of respondents allowed me, according to the established objectives, to analyze, classify and present the results in the form of two sections: *The reform management – the weak link of the strategy regarding the consolidation of* *the public administration* and *Current trends in the management of local tax and tax departments/services. Effects on staff motivation and job satisfaction, with related subsections*.

3. Results

The reform and reformation of the public sector in Romania proved to be an extremely necessary problem, but difficult to implement taking into account the previous attempts and the rather long period now taken into account for the achievement of the objectives. It is true, the effects of reforms become visible after several years (Bezes & Palier, 2018). It was desired to change the action of the administrative system in depth, political support was present and a great absorption capacity of these proposals was expected from the socio-economic and fiscal environment.

As for the local tax administration, within the departments or services of local taxes and taxes, through the reform strategy, measures were instituted to correct some shortcomings regarding the body of civil servants, their selection and promotion, the relationship between the administration and the citizen, the reduction of bureaucracy, digitization of the system, depoliticization and the elimination of political clientelism, along with the establishment of new, equitable bases for local taxes and fees. The questionnaires for this research, as we have already pointed out, contain a series of common questions addressed to both civil servants and taxpayers. We would like to mention that in the present case, the official means the personnel who work within the departments or services of local taxes and fees (both the persons appointed to public positions and the contractual personnel).

In the first item of the questionnaire, we requested the expression of opinion regarding the necessity of the reform (*Do you consider that a deep reform of the Romanian public administration was necessary?*). The analysis of the answers gave fairly close percentages. Thus, 74.19% of the officials consider this appropriate, 9.67% answered negatively, and 16.13% chose the option I don't know / don't answer. For the answers given by the taxpayer, we recorded the following percentages: 79% gave affirmative answers, 4.66% of the subjects believe that this was not necessary, and 16.33% chose the option I don't know / I don't answer.

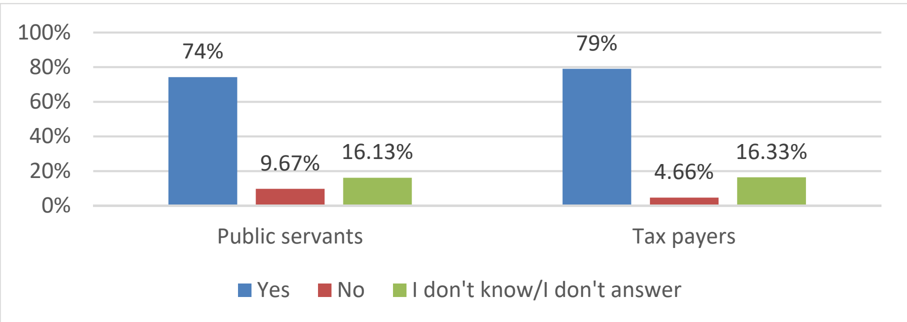

Figure 10. The need for reform

The very high percentage of respondents who chose the option Yes, denotes the agreement but also the need for fixing, and rethinking some problems related not only to local taxes and fees but to the entire administrative system. It is obvious the perception of a very low efficiency and quality of the administration and local public services both on the part of the taxpayers and the civil servants taking into account the result obtained. It would not be considered appropriate to change something that is working and getting the expected results.

Taking into account the governance programs from 2001-2020, the updated, consolidated, and republished versions of the Local Public Administration Law no. 215/2001, the Strategy for the consolidation of the public administration 2014-2020 and the Strategy for the development of the public function 2016-2020, we considered that there is a sufficient period of time to introduce items through which I can highlight how the objectives of the reform have been achieved from the perspective the two groups of subjects. Through item 10, questionnaire taxpayers (7 sub-items) and item 3 - civil servants (12 sub-items) we formulated the following requirement for the respondents: *You can state that following the public administration reform process, at the level of local tax and tax departments/services success...*

The requirement was common, and the first 6 items present in the questionnaire for taxpayers were common with 6 other items in the questionnaire for civil servants because we intended to make a comparison between the answers. The common items referred to the creation of a body of competent civil servants dedicated to their work, the change for the better in the relationship between the local tax administration and the citizen, increasing the interest of civil servants for the efficiency and public service modernization, reducing bureaucracy, digitizing the public administration, settling on new, fair bases of local taxes and fees, a better representation of taxpayers' interests in the decision-making process at the level of local tax administration. I offered as answer options totally agree / agree / partially agree / disagree / totally disagree / don't know / don't answer. The answers given by the two groups of respondents can be seen from the table below.

Table 1. Comparative analysis of the answers regarding the fulfillment of the objectives reform at the level of local fiscal administration

Indicators	Respondents	Totally agree / agree (%)	Partial agreement (%)	Totally disagree / disagree (%)	I don't know / I don't answer (%)
Creating a **body of public servants** competent and dedicated to their professional activity	I don't know / I don't answer	28	44	18.67	9.33
	Public servants	37.09	42.75	17.74	2.41
Changing the **relationship** between the local tax administration and the citizen for the better	Tax payers	29	38.33	25.33	7.33
	Public servants	41.94	43.54	12.99	0.90
Increasing the **interest** of civil servants for the efficiency and modernization of the public service	Tax payers	28.33	33	31.33	7.33
	Public servants	50.79	38.70	9.66	0,80
Reducing **bureaucratie**	Tax payers	21	28.33	43	7.66
	Public servants	34.67	29.84	34.68	0,80
Digitization of public administration	Tax payers	39	34.33	19.16	7
	Public servants	50	31.45	17.73	0.80
Placing local taxes and fees on new, equitable **bases**	Tax payers	27.33	24.67	30.66	17.33
	Public servants	41.36	24.19	25.81	5.64
Better **representation** of your interests in the **decision-making process** at the local tax administration level	Tax payers	24	26	36	14
	Public servants	0	0	0	0

There are large and very large differences for the totally agree / agree option between the two groups of respondents for each of the sub-items. While half of the civil servants appreciate that it has been possible to increase the interest of civil servants for the efficiency and modernization of the public service (50.79%), the taxpayers totally agree or agree with this statement only in a percentage of 28.33.

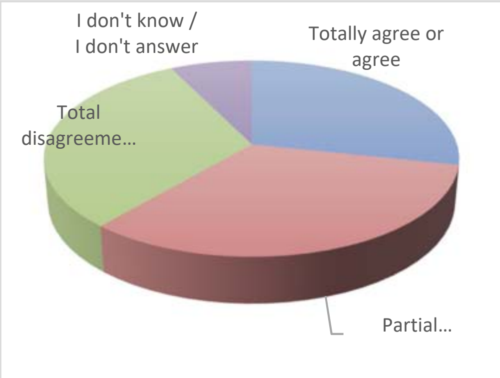

Figure 11. Tax payers' opinion regarding the increase in the interest of civil servants for the efficiency and modernization of the public service

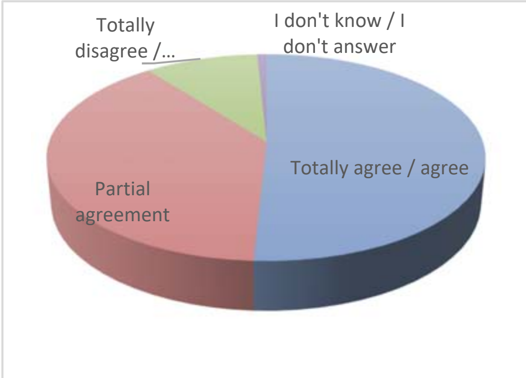

Figure 12. The opinion of public servants regarding the increase of public servants' interest in the efficiency and modernization of the public service

For the sub-item creating a body of competent public servants dedicated to their professional activity, the results were surprising: only 28% of taxpayers *totally agree or agree* with the statement, and 37.09% of civil servants. For *partial agreement*, close percentages were obtained – 44.00 tax payers and 42.75 public servants, as for the *total disagreement / disagreement* - 18.67% tax payers and 17.74% of the rest of the subjects.

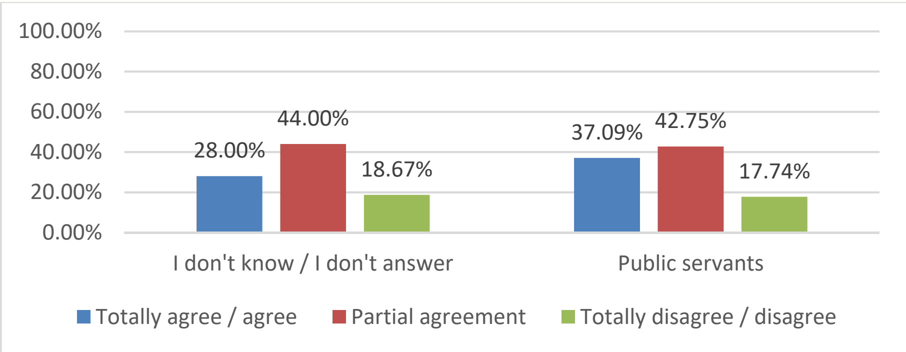

Figure 13. Respondents' opinion regarding the creation of a body of competent and dedicated public servants to their professional activity

A body of professional officials means a professionalized administrative system that takes into account the institutional perception and image and the level of trust of the beneficiaries. The conviction that civil servants have their own interests and obtaining benefits as their objective is still dominant, that manipulation, lack of ethics, immorality and corruption are specific to them, as E. Vigoda-Gadot stated since 2007. The Romanian public administration, the public service, has specifically what E.M. Berman (1997) called public cynicism, that is, that conviction or belief that both government policies and officials at the start are under the sign of corruption, incompetence and the desire to take advantage of the citizen.

Public cynicism is associated with a reduced level of trust and a sense of belonging to the community, but according to the author mentioned above, these aspects are much more visible when it comes to public services with fiscal activity, such as taxes, fines, fees, and a cause of this phenomenon is the lack of information.

Table 2. Determination of the Pearson correlation coefficient for the variables Qualities (body of public servants) and Interest (for public service efficiency) in the case of public servants

		Creating a body of public servants competent and dedicated to their professional activity	Increasing the interest of public servants for the efficiency and modernization of the public service
Creating a body of public servants competent and dedicated to their professional activity	Pearson Correlation	1	.540**
	Sig. (2-tailed)		0.000
	N	121	121
Increasing the interest of public servants for the efficiency and modernization of the public service	Pearson Correlation	.540**	1
	Sig. (2-tailed)	0.000	
	N	121	123
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).			

Analyzing the result obtained following the verification of the Pearson correlation, it follows that, in the case of civil servants, the level of interest, competence, and professionalism determines the increase in the level of efficiency and modernization of the public service. A similar result was also obtained in the case of checking the correlation level for the answers given by tax payers (r = .498).

Table 3. Determination of the Pearson correlation coefficient for the variables Qualities (body of officials) and Interest (for the efficiency of the public service) - in the case of tax payers

		Creating a body of Public servants competent and dedicated to their professional activity	Increasing the interest of civil servants for the modernization and efficiency of the public service
Creating a body of Public servants competent and dedicated to their professional activity	Pearson Correlation	1	.498**
	Sig. (2-tailed)		0.000
	N	272	264
Increasing the interest of civil servants for the modernization and efficiency of the public service	Pearson Correlation	.498**	1
	Sig. (2-tailed)	0.000	
	N	264	278
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).			

A very big difference was registered in the case of the sub-item referring to *the settling of local taxes and fees on new, equitable bases*. Are *totally agree / agree with* this statement 41.36% of the official respondents and only 27.33% of the tax payers, which means a significant difference between the two groups of subjects (14.03%), approximate difference recorded and for the subitem referring to *the change for the better in the relationship between the local fiscal administration and the citizen*; 41.94% of officials are convinced of the achievement of this objective, and taxpayers expressed their agreement or total agreement in a percentage of 29%.

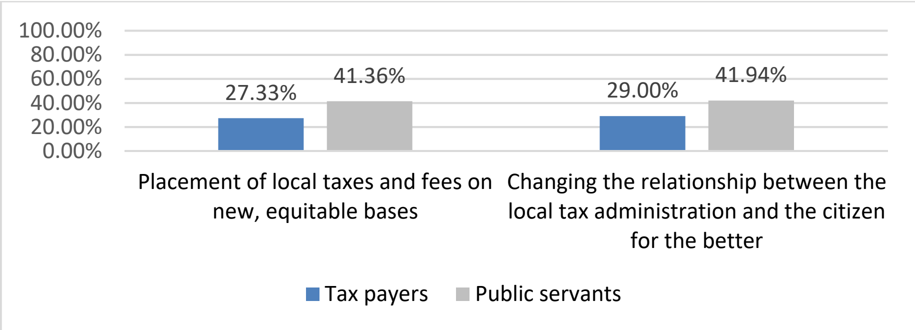

Figure 14. Comparison of the answers given by the two groups of subjects regarding fair taxation and the change for the better in the fiscal administration-citizen ratio (totally agree option)

Table 4. Pearson correlation coefficient regarding the variable tax administration-citizen **ratio**, fair taxation (tax payers version)

		Changing the relationship between the local tax administration and the citizen for the better	Placing local taxes and fees on new, equitable bases
Changing the relationship between the local tax administration and the citizen for the better	Pearson Correlation	1	.552**
	Sig. (2-tailed)		0.000
	N	248	240
Placing local taxes and fees on new, equitable bases	Pearson Correlation	.552**	1
	Sig. (2-tailed)	0.000	
	N	240	248
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).			

Analyzing the correlation coefficient obtained after checking the answers provided by taxpayers and public servants (r = .522, for 240 taxpayers, respectively r = .572, for 117 Public servants), we can affirm the fact that both groups of respondents believe that fair, equitable taxation will change for the better the relationship between the citizen and the tax administration. Behind this consideration, we find a very current problem related to fiscal policy and the fiscal system perceived as unequal or unfair. It is still not understood that fiscality, respectively taxation, has a well-established role in the becoming and development of society, and we consider it necessary to show the importance of what is financed by the taxes collected. It is desirable to promote a simplified, stable, and easier-to-understand tax system.

Subject to multiple changes in the short term, taxation and charging confuse Taxpayers and do not give respite to the awareness of their role.

Table 5. Pearson correlations regarding the variable Fiscal administration-citizen **ratio**, fair taxation (public servants version)

		Changing the relationship between the local tax administration and the citizen for the better	Placing local taxes and fees on new, equitable bases
Changing the relationship between the local tax administration and the citizen for the better	Pearson Correlation	1	.572**
	Sig. (2-tailed)		0.000
	N	123	117
Placing local taxes and fees on new, equitable bases	Pearson Correlation	.572**	1
	Sig. (2-tailed)	0.000	
	N	117	117

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Significant differences between the respondents were recorded for the reduction of bureaucracy, the digitization of public administration, and the creation of a body of Public servants dedicated to their professional activity. It is natural for the taxpayer to look at things differently from outside the system (for example, 50% of civil servants believe that the digitization of the system has been successful, Taxpayers and 39%), but in the conditions where 62.10% of civil servant respondents have seniority in the system between 10 and over 20 years, only 37.09% agree with the existence of a body of competent officials who show the spirit of duty in the service of the citizen and only 34.67% affirm that the reduction of bureaucracy has occurred, already appear question marks.

Table 6. Pearson correlation coefficient for the professionalism variable (applied to civil servants)

		Creating a body of public servants competent and dedicated to their professional activity	Reducing bureaucracy, simplifying procedures	Public administration digitization
Creating a body of public servants competent and dedicated to their professional activity	Pearson Correlation	1	.435**	.493**
	Sig. (2-tailed)		0,000	0,000
	N	121	121	121
Reducing bureaucracy, simplifying procedures	Pearson Correlation	.435**	1	.570**
	Sig. (2-tailed)	0,000		0,000
	N	121	123	123
Public administration digitization	Pearson Correlation	.493**	.570**	1
	Sig. (2-tailed)	0,000	0,000	
	N	121	123	123

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Comparing the results obtained through the SPSS program, we obtained a correlation coefficient of over .500 for both groups of respondents, which leads me to affirm that, at the present moment, we cannot talk about reducing bureaucracy, digitization, or increasing the level of professionalism of civil servants, but certainly the three values are interdependent. We believe that the starting point is the increase in the level of professionalization of the activity of civil servants, which will automatically determine the opening to the computerization of the public administration and the reduction of the level of bureaucracy (Pochard, 2011). Cutting red tape is first and foremost an essential economic policy issue. At the level of local tax and fees departments or services, more objectivity on real administrative costs and a clear distribution of tasks would reduce this phenomenon.

Table 7. Pearson correlation coefficient for the professionalism variable (applied to tax payers)

		Creating a body of public servants competent and dedicated to their professional activity	Reducing bureaucracy	Public administration digitization
Creating a body of public servants competent and dedicated to their professional activity	Pearson Correlation	1	.508**	.441**
	Sig. (2-tailed)		0.000	0.000
	N	272	262	265
Reducing bureaucracy	Pearson Correlation	.508**	1	.471**
	Sig. (2-tailed)	0.000		0.000
	N	262	276	266
Public administration digitization	Pearson Correlation	.441**	.471**	1
	Sig. (2-tailed)	0.000	0.000	
	N	265	266	279

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

We considered that an objective is met when there is a balance between the expectations of the beneficiaries (citizens) and the quality of public services provided (Masood et. al., 2015). We cannot mark as resolved these aspects that I wanted to capture by formulating the item, as long as the citizens do not find their interests represented or satisfied, and the officials themselves put under the sign of uncertainty professional aspects that concern them directly. We recognize the existence of an administrative culture based on traditions, values, priorities, daily routines, procedures, and mindsets (Pochard, 2011). The lack of civil servant responsiveness is an important aspect of change management. We live in a competitive and demanding world; a computerized society has much higher expectations. Traditional administrative practices no longer fit the new contexts. The public service needs to adapt its structures, processes, and procedures.

If 50% *total agreement/agreement* was reached regarding *the digitization of the public administration system* (but let's not forget the contribution of the Covid-19 pandemic!) and close percentages for the partial agreement variant between the two classes of subjects for subitems related to body quality of officials (42.75% officials / 44% taxpayers), reduction of bureaucracy (officials - 29.84%, taxpayers - 28.33%) and legitimacy of taxes (taxpayers -

24.67% / officials - 24.19 %), after more than a decade and a half of reforms we are somewhere between one-tenth and one-third of achieving the objectives, which is very little for such a long period, and with such percentages we cannot talk about performance.

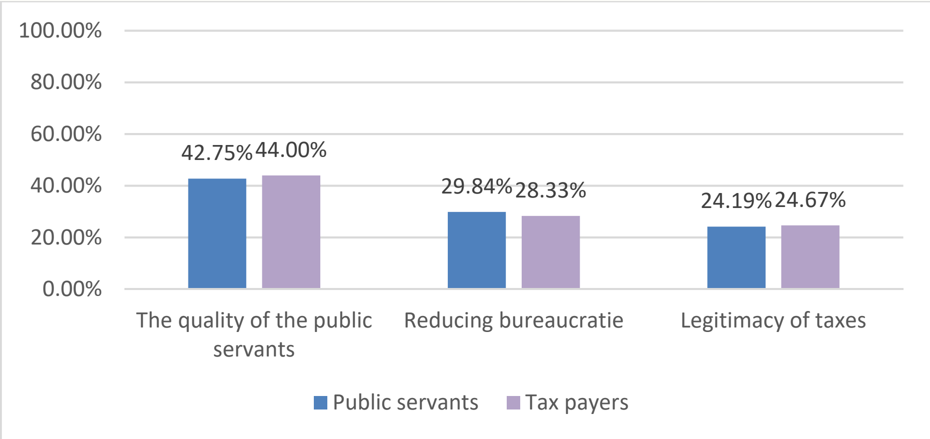

Figure 15. Subjects' assessment of the efficiency of the quality of civil servants, the reduction of bureaucracy and the legitimacy of taxes

Let's not forget that we are in the midst of the era of information technology, that the speed of data transmission and ever-increasing requirements generate pressure; computerization has imposed itself at the level of the social and organizational environment, but it is a new reality to which people, taken individually, especially at a certain age, have adapted much harder, lost the rhythm, replaced the previous normal with something else - another type of communication and interpersonal relations, another way of participating in the life of the organization, another work climate, other culture, and other values.

The results obtained for Item 10 (Taxpayers) by using the SPSS program led to the following conclusion: digitization of the public administration is in close correlation with the existence of a body of competent and dedicated Public servants to the activity they carry out (r =.441), can change the relationship between the public administration and the citizen for the better (r = .451), reducing bureaucracy (r = .471) and can be a better way of representing citizens' interests in the decision-making process (r = . 459).

Table 8. Pearson correlation coefficients for the digitization of public administration - Taxpayers

		Creating a body of public servants competent and dedicated to their professional activity	Changing the relationship between the local tax administration and the citizen for the better	Reducing bureaucracy	Increasing the interest of civil servants for the modernization and efficiency of the public service	Placing local taxes and fees on new, equitable bases	Better representation of your interests in the decision-making process at the local tax administration level
Public administration digitization	Pearson Correlation	.441**	.451**	.471**	.396**	.435**	.459**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	265	266	266	268	240	251

Public servants (Item 3), on the other hand, believe that public administration digitization depends primarily on improving the quality of management at the level of departments and services (r = .587, identified by 122 out of a total of 124 respondents), will increases in proportion to the reduction of bureaucracy and simplification of procedures. Achieving a high degree of public administration digitization will be possible to the extent that the interest of civil servants in the efficiency and modernization of the public service will increase.

Table 9. Pearson correlation coefficients for Public administration digitization – public servants

		Creating a body of public servants competent and dedicated to their professional activity	Changing the relationship between the local tax administration and the citizen for the better	Increasing the interest of civil servants for the modernization and efficiency of the public service	Reducing bureaucracy	Placing local taxes and fees on new, equitable bases	Better representation of your interests in the decision-making process at the local tax administration level
Public administration digitization	Pearson Correlation	.493**	.492**	.510**	.570**	.527**	.570**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	121	123	123	123	117	114

In the taxpayers' questionnaire, a sub-item was included regarding the respondents' agreement regarding *a better representation of interests in the decision-making process at the local tax administration level*. 24% of the respondents *totally agreed/agree*, 26% chose the *partial agreement* option, 36% *totally disagree/disagree*, and 14% *don't know/don't answer*.

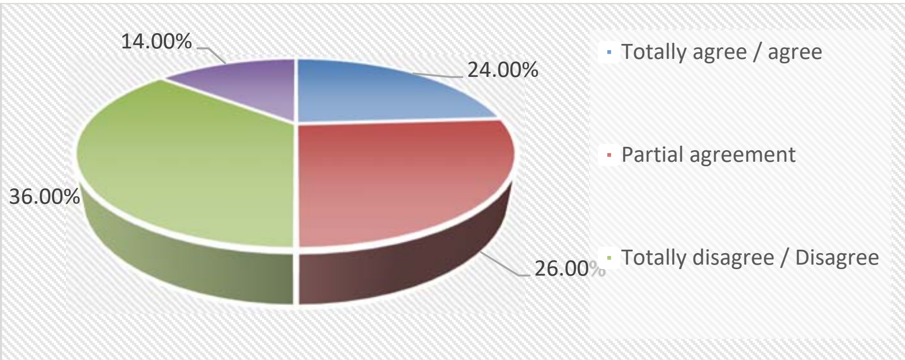

Figure 16. Tax payers' opinion regarding the representation of interests in the decision-making process at the level of local tax administration

Taxpayers believe that a better representation of interests in the decision-making process is defined by the change for the better in the relationship between the local public administration and the citizen, by the increase in the interest of civil servants for the modernization and efficiency of the public service and above all by settling on new bases, equitable of local taxes and fees, the correlation coefficient in this last case being r = .692, the number of respondents being 233.

Table 10. Pearson correlation coefficients for the representation of interests in the decision-making process at the level of the local tax administration – tax payers

		Creating a body of public servants competent and dedicated to their professional activity	Changing the relationship between the local tax administration and the citizen for the better	Reducing bureaucracy	Public administration digitization	Increasing the interest of civil servants for the modernization and efficiency of the public service	Placing local taxes and fees on new, equitable bases
Better representation of your interests in the decision-making process at the local tax administration level	Pearson Correlation	.427**	**.601****	.597**	.459**	.598**	**.692****
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	247	250	248	251	252	233

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The implementation of tax policy becomes difficult for tax administrations because the relationship between taxpayers and them is essentially a sensitive aspect of the relationship between the state and the citizen. A different attitude on the part of the taxpayer requires a different approach on the part of tax policy and administration. The initiative of administrative and fiscal reforms does not guarantee a better relationship between taxpayers and fiscal authorities (Bazin, 2014). Citizens are more open and willing to pay when they know their money is being spent effectively on services they need. A stable fiscal environment means trust and responsibility on the part of all actors involved. You cannot build trust in the tax system without accountability, without reciprocity, equity, and justice. In addition, reformers' efforts may be undone by a lack of adaptation to the specific national context.

Public servants identify the same elements of connection between the increase in the degree of representation of Tax payers' interests in the decision-making process, respectively the change for the better in the relationship between the local public administration and the citizen (r = .638, correlation identified in several 114 respondents from total of 124). The increase in the interest of civil servants in the efficiency and modernization of the public service can also be associated with a body of civil servants competent and dedicated to the activity, where the correlation coefficient was r = .585, respectively r = .604, as well as the fair determination of taxes and local taxes (r = .655).

Decisions at the level of local fiscal administration are a corollary of local public administration decisions. The percentages balanced in the negative sense for the first two answer options (together they represent 50% of the number of taxpayers respondents!) compared to the 36% *disagreement/total disagreement* become an indicator of the distance between the administration and the citizen, but also of the lack of active involvement of citizens in the decision-making process that concern them either personally or at the community level. On the one hand, there is a problem of the quality of the relationship, and on the other, a decrease in the degree of trust in the public institution.

Table 11. Pearson correlation coefficients for the *representation of interests* in the decision-making process at the level of the local fiscal administration – Public servants

		Creating a body of public servants competent and dedicated to their professional activity	Changing the relationship between the local tax administration and the citizen for the better	Increasing the interest of civil servants for the modernization and efficiency of the public service	Reducing bureaucracy, simplification of procedures	Public administration digitization	Placing local taxes and fees on new, equitable bases
Better representation of your interests in the decision-making process at the local tax administration level	Pearson Correlation	**.604****	**.638****	.585**	.572**	.570**	**.655****
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
	N	113	114	114	114	114	111

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

A reform of the public administration was desired so that it responds to the demands and needs of society, and of the taxpayers (Fallon and Joris, 2009). We appreciate the reform strategy as an innovative one, but the management of this strategy has greatly altered the results. If the change is not for the better and the effort is without positive results, it is natural to ask ourselves whether or not it is still necessary to talk about reform and reformation, about the modernization of the management of the organization or the public service, about satisfied social expectations or the responsiveness of the public institution to the needs of citizens . The vision of change management without being doubled by the ability to implement and continuously monitor this process will not produce the desired changes.

For a better penciling of the picture of the objectives achieved or the degree of their achievement, I added, in the questionnaire of civil servants, to the same item, another 5 sub-items through which I wanted to find out to what extent they agree with the reality the achievement of the objectives such as *the development of the management capacity of local tax authorities, the harmonization of the legislative framework with the EU regulations, the improvement of the quality of management at the level of services and departments, the depoliticization and elimination of political clientelism, the creation and operation of a system of recruitment, employment, and advancement based on merit and professionalism*.

Regarding the management, recruitment, hiring, and advancement of civil servants in terms of leading or execution posts, the association between the public institution and political affiliation or sympathy is visible in the responses of the participating subjects. G.R. Ferris and K.M. Kacmar (1992), based on studies, demonstrated that as organizations are perceived to be politicized, they are also considered to be less ethical and fair.

E. Vigoda-Gadot (2007) called this phenomenon the spillover effect, i.e. the spillover, with quotation marks, of the attitudes, skills, and behaviors specific to the political sphere in the arena of administrative organizations, producing the contamination effect, a transfer of the image of the politician in the administrative space, harmful to the image of the latter. The results shown in the figure below.

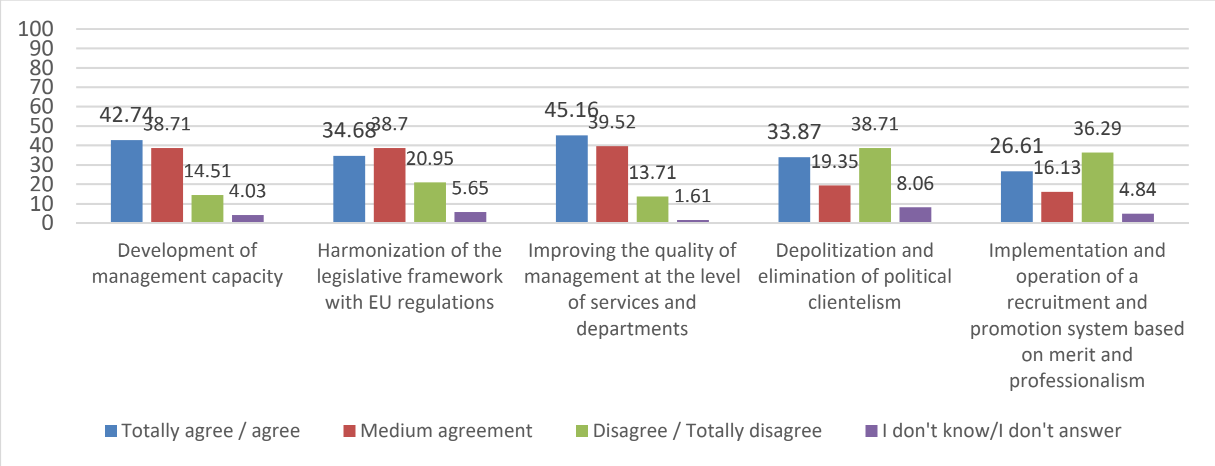

Figure 17. Officials' agreement regarding the achievement of reform objectives at the level of local fiscal administration

Most of the officials consider that the development of management capacity has been achieved in proportion to 42.74%, (but the average agreement which represents 38.71% is not to be neglected either!) and the improvement of management quality at the level of tax departments and services and local taxes (45.16%), the average agreement, in this case, being 39.52%. Following the analysis of the answers regarding depoliticization and the elimination of political clientelism, we noted a percentage of 38.71 for the *disagreement/total disagreement* option, a percentage higher than that *agreeing* (33.87%), and the percentage regarding recruitment, employment, advancement based on professionalism and meritocracy - 36.29% *disagree or strongly disagree* while *agreeing/strongly agree* were chosen by 26.61% of respondents.

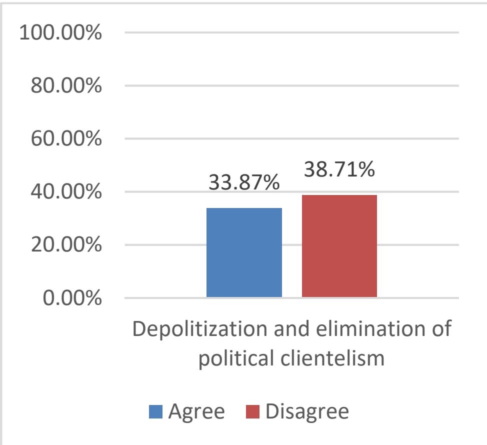

Figure 18. Public officials' opinion regarding depoliticization and the elimination of political clientelism

Figure 19. Public officials' opinion regarding Recruitment, employment, advancement based on professionalism and meritocracy

The obtained percentages indicate the presence in the dynamics of the organizational management of the public service of politicization and political clientelism. Civil servants are required to be neutral and stable, as they the guarantee of an adequate response to the interests of the citizens, but they are positioned between the interests of the political leaders and the managers of the organization. Politicization doubled by clientelism is a politicization of favoritism, far from what L. Rouban (2009) claimed, that there is politicization among the public administration, formal politicization - a legal and legitimate method of recruitment and promotion (apud. T. Hustedt et al ., 2014).

The practice of favoritism, however, is informal and closed, appointments are made in violation of formal rules and administrative traditions aimed at bureaucratic neutrality. It is that kind of politicization that authors such as G.B. Peters and J. Pierre (2004) stated that it represents the replacement of meritocracy criteria with those based on political considerations in the process of selecting, promoting, retaining, rewarding, and sanctioning members of the public service. To clarify these nuanced differences in politicization, G.B. Peters (2004), proposed the classification of politicization into six subtypes: direct politicization (equivalent to the recruitment of political loyalists to permanent positions), *professional politicization* (recruitment of political supporters), *unnecessary politicization* (recruitment to supervisory positions of civil service activities), *anticipatory politicization* (when a new government is expected, civil servants appointed according to the previous criteria leave their posts), *double politicization* (decided by Parliament and Government) and *social politicization* (dictated by the influence of other social actors on the recruitment or career of civil servants).

There are other classifications of politicization and I consider it appropriate to recall T. Hustedt and H. Houlberg Salomonsen (2014) who establish three forms of politicization - *formal, functional, and administrative*; the first type reflects recruitment beyond the principle of merit; functional politicization refers to the role of civil servants about the reaction to politics, and administrative politicization is related to the relationship between civil servants and political advisers in ministerial offices, advisers who can filter, modify or even obstruct the access and content of civil servants' opinions to the higher forum.

From the point of view of the aforementioned authors, both formal and functional politics meet the criteria of democratic legitimacy. Functional politicization consists in how the bureaucracy identifies itself in skills and behaviors specific to its role in society. Administrative politicization is considered a mechanism by which ministerial advisors politicize the proposals/information provided by the permanent public service (Cooper, 2021). We could say that these three types coexist, they develop differently from one historical stage to another, from one country to another, and politicization is perceived as being in contradiction with the administrative system at the level of our country due to informal politicization and the development of its mechanisms.

What the participating subjects express are reactions to this type of politicization that has expanded compromising the role of functional politicization and administrative politicization, which can become self-regulating mechanisms at the level of the political-administrative system (Huestedt and Houlberg Salomonsen, 2014). Any public system also involves a degree of politicization. Political culture influences administrative culture and it is unacceptable when public policies are discontinuous, and the public administration system may adopt a certain style that suits elected and appointed officials rather than ordinary public officials who become vulnerable, considering that managerial decisions as appointments are politically dictated, that this politicization subtly dictates the management of human and material resources.

Corroborationg the answers of the two groups of subjects, we can observe that the mechanisms of politicization are considered exclusively negative. Politicization itself would not be a problem as long as we can talk about the neutrality and impartiality of the public service. In this context, we also note the arguments of D. Stephane (2002) that the administration can be politicized with the aim of placing resources and personnel directly at the disposal of the party in power, a situation in which the administration becomes an instrument of patronage or clientelism, and a second argument - by determining as many officials as possible to politically support the elected, the administration becomes a much more effective tool for confirming and supporting government policies, in other words, the officials become loyal to the government program at that moment because, regardless of the hierarchical level, they must to respect the law and the public interest. The adoption of normative acts obliges to respect them and renounce political sympathies.

What was not understood and did not succeed through the reform of the public administration in Romania was the recruitment, promotion, and maintenance in the system of competent, experienced, neutral civil servants capable of supporting public policies.

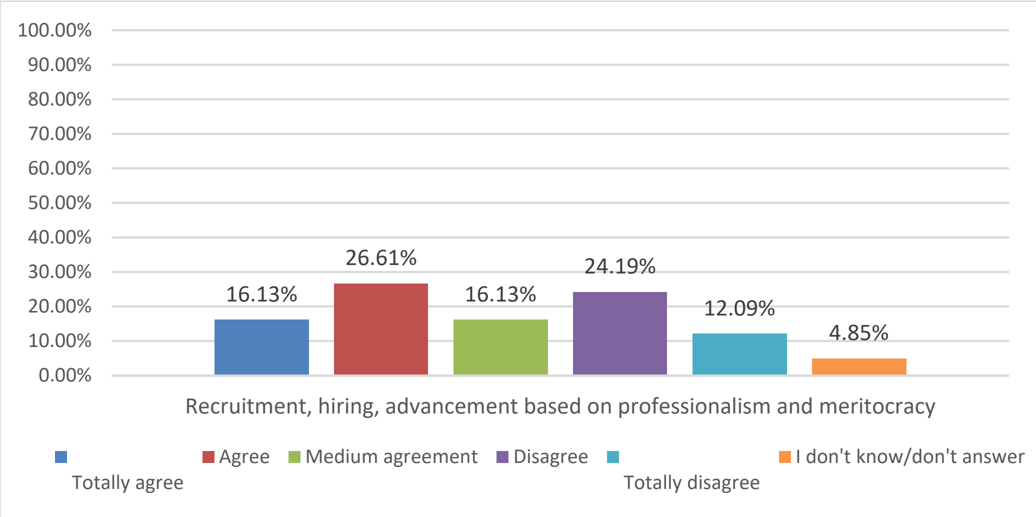

Figure 20. The opinion of civil servants regarding recruitment, employment, advancement based on professionalism and meritocracy

Through item 3, subitem 11, we asked the subjects - civil servants participating in the research to express their agreement regarding the implementation and operation of a recruitment and employment system based on merit and professionalism as a result of the public administration reform. 42.74% of the participants expressed their agreement (*totally agree and agree*), with *the medium agreement* - 16.13%; *the totally disagree and disagree* option got 36.28%, and *I don't know/don't answer* - 4.85%. The percentage of those who expressed their agreement is close to that of those who expressed their disagreement, which means that the occupation of public office, recruitment, and promotion is done only to a small extent according to professional criteria. The public administration system is still tributary to political affiliation and favoritism or criteria other than open competition, professional merit, and competence. In such conditions, we cannot talk about professional public administration or effective organizational management. It takes neutrality, competence, and motivation. A well-implemented fiscal policy must be backed by a personnel policy or the tools of a personnel policy based on professional ethics and deontology transformed into management practices.

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STRENGTH OF FACTORS IN 3^3 FACTORIAL DESIGNS USING BAYESIAN ANALYSIS

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Abstract

The study proposes to consider factorial design at three levels and identify all significant factors based on its inherent strength. The methodology considers full, fractional, and reduced factorial designs with three factors each at three levels, to examine the effectiveness of factors in these models through simulation and employing real data. By identifying and quantifying the Bayes factors through simulated datasets, the true strength of the main/interaction effects in these three designs were discovered. Finally, the study concludes that reduced factorial design produces better results than traditional one-third fractional factorial designs when there are no other constraints to adding more factors to the model for analysis.

Keywords: 3^3*factorial design; Zellner's g prior; Jeffreys-Zellner-Siow prior; Hyper- g priors; strength of factors*

Introduction

Factorial designs are being widely used in experiments involving several factors and where it is necessary to study the impact of the factors or combination of factors on a process. The main goal is to identify the significant factors from a set of main effects and interactions. It may be noted that as the number of factors increases the total number of combinations becomes unwieldy. The present research considered the factorial design with p factors, each at three levels such as "low", "intermediate" and "high" levels of a factor. The factorial designs at three levels have been well exploited and analyzed considering all factors, confounded completely and partially and lastly as fractional factorials.Xu et al. (2009) discussed developments in non-regular fractional factorial designs, particularly optimality criteria, projection properties, resolutions, and aberration criteria. Baba et al. (2013) proposed the usefulness of the empirical Bayesian approach to the saturated factorial designs and observed predictions and inferences for the parameters. Espinosa et al. (2016) proposed a new approach to screen for active factorial effects from replicated factorial design using the potential outcomes framework and based on sequential posterior predictive model checks. Rouder et al. (2017) presented the Bayes Factor approach to multi-way ANOVA with hierarchical models for fixed, random effects, with-subjects, between-subjects, and mixed designs. Schwaferts and Augustin (2018) applied Bayes Factors to get optimal decisions in a study on the framework of hypothesis-based Bayesian decision theory with robust loss function and step-by-step guidelines. Khaw et al. (2019) identified the best extraction condition of factors from the application of the six-factor fractional factorial design. Lakens et al. (2020) have provided comprehensive explanations of the calculation and interpretation of Bayes Factors for several tests. In educational research, the Bayesian analysis for treatment and control groups was discussed through the factorial designs by Kessler et al. (2020). Sokac et al. (2021) addressed the limitations of optimization and mathematical model for improving composting processes.

Heck, et al. (2021) outlined a thorough knowledge of Bayesian variable selection, Bayesian evaluation of cognitive models, and opportunities for Bayes Factor applications. Gardini et al. (2021) gave an idea on the log-transformation of a response variable by applying the Bayesian analysis of variance mixed models to examples and simulation datasets. Egburonu et al. (2021) discussed a balanced two-way analysis of variance of three cases such as the factors are fixed, random, and mixed by applying the Bayesian techniques. Gromping (2021) developed an algorithm for a two-level regular fractional factorial design with two-factor interactions. Ming-Chung Chang (2022) used the Bayesian approach for the minimum aberration criteria for many applications. Vijayaragunathan and Srinivasan (2022) discussed the comparison of Bayes Factors in both 2^3 and 2^4 full, fractional and reduced factorial designs.

The present study proposed considers a factorial design that includes all significant factors based on its strength by analysing full, fractional, and reduced factorial designs with three factors each at three levels adopting Bayesian approach Under Bayesian approach it is important to identify suitable priors to examine the strength/effectiveness of factors in these models. Thus, by identifying and quantifying the Bayes Factors through simulated datasets, the true weightage of the main/interaction effects in these three designs were discovered. Finally, the study concludes that the reduced factorial design produces better results than traditional one-third fractional factorial designs when there are no serious constraints in terms of time and resources for adding more factors to the model. The following section provides an algorithm for studying the strength of factors and then an illustration is provided for the same. The reliability of the results are studied through a simulation study and conclusions are provided at the end.

2. Algorithm for finding the strength of factors in 3^3 factorial design

In the 3^3 full, fractional, and reduced factorial designs, the following steps are to be followed to analyze, evaluate and identify the strength of factors.

Step 1: Consider the appropriate data for a 3^3 full factorial design and analyze the same to identify the significant main and interaction effects.

Step 2: Construct a fractional factorial design based on suitable confounding factors and then check its significance in the model.

Step 3: Generate a reduced factorial design according to the significant factors from the 3^3 full factorial design.

Step 4: Compute the Bayes Factor values for 3^3 full, fractional, and reduced factorial designs to compare the strength of factors while incorporating them into these designs.

Step 5: To extend the findings, the study employed simulated datasets to uncover the strength of factors through a variety of Bayesian priors and draw comprehensive and useful conclusions based on the strength of the factors.

The present research considers the basic 3^3 factorial experimental design to find the most significant factors in full factorial, fractional and reduced factorial designs. When the experimental run is large, usually a fractional factorial design is preferred which incorporates all major elements in the design. Let each factor be tested at three levels, with a_0, a_1, and a_2, is the three levels of a; b_0, b_1, b_2 being the three levels of b; and c_0, c_1, c_2 being the three levels of c, and so on. $[a_i]$ is the total number of treatment combinations with an a_i^{th} level. $[a_1]-[a_0]$ at the 0^{th} level, and $[a_2]-[a_1]$at the first level, there are two reactions to a unit amount of the factor. When one looks at a graph with the levels of factor a on the x-axis and the responses on the y-axis, one can see that when $[a_2]-[a_1]$ is almost equal to $[a_1]-[a_0]$, the responses will lie on a straight line, therefore, the linear effect of factor a is measured by the average of $[a_2]-[a_1]$ and $[a_1]-[a_0]$. When $[a_2]-[a_1]$ differs significantly from $[a_1]-[a_0]$, the replies will follow a parabola rather than a straight line. As a result, the study uses the difference between $[a_2]-[a_1]$ and $[a_1]-[a_0]$ to calculate the factor's quadratic effect. The linear and quadratic effects of a, indicated by $\mathrm{A_L}$ and $\mathrm{A_Q}$ respectively, are obtained by utilizing standard divisors to express the effects on a unit-based comparison as follows.

$$\boldsymbol{A_L=\frac{1}{r\,3^{n-1}}([a_2]-[a_0])} \quad (1)$$

$$\boldsymbol{A_Q=\frac{1}{2r\,3^{n-1}}([a_2]-2[a_1]+[a_0])} \quad (2)$$

Each treatment combination is replicated r times. The remaining elements for linear and quadratic effects can be defined in the same way. Any two-factor interaction has four degrees of freedom, which are classified as linear × linear, linear × quadratic, quadratic × linear, and quadratic × quadratic. The AB interaction can be divided into partitions as

$$\boldsymbol{A_LB_L=\frac{1}{2r\,3^{n-2}}(a_2-a_0)(b_2-b_0)}$$

$$\boldsymbol{A_QB_L=\frac{1}{4r\,3^{n-2}}(a_2-2a_1+a_0)(b_2-b_0)}$$

$$\boldsymbol{B_Q=\frac{1}{4r\,3^{n-2}}(a_2-a_0)(b_2-2b_1+b_0)}$$

$$\boldsymbol{A_QB_Q=\frac{1}{8r\,3^{n-2}}(a_2-2a_1+a_0)(b_2-2b_1+b_0)}$$

The total yields are substituted for the treatment combinations with the provided levels of a *and* b*, and the multiplications are done as usual. Similarly, other two-factor interactions can be partitioned into single degrees of freedom. ABC is a three-factor interaction with 8 d.f. that can be partitioned into a single d.f. as illustrated below.*

$$\boldsymbol{A_LB_LC_L=\frac{1}{4\,r\,3^{n-3}}(a_2-a_0)(b_2-b_0)(c_2-c_0)}$$

$$\boldsymbol{A_LB_LC_Q=\frac{1}{8\,r\,3^{n-3}}(a_2-a_0)(b_2-b_0)(c_2-2c_1+c_0)}$$

$$\boldsymbol{A_LB_QC_L=\frac{1}{8\,r\,3^{n-3}}(a_2-a_0)(b_2-2b_1+b_0)\,(c_2-c_0)}$$

$$\boldsymbol{A_LB_QC_Q=\frac{1}{16\,r\,3^{n-3}}(a_2-a_0)(b_2-2b_1+b_0)(c_2-2c_1+c_0)}$$

$$\boldsymbol{A_QB_LC_L=\frac{1}{8\,r\,3^{n-3}}(a_2-2a_1+a_0)(b_2-b_0)(c_2-c_0)}$$

$$\boldsymbol{A_QB_LC_Q=\frac{1}{16\,r\,3^{n-3}}(a_2-2a_1+a_0)(b_2-b_0)(c_2-2c_1+c_0)}$$

$$A_Q B_Q C_L = \frac{1}{16\, r\, 3^{n-3}} (a_2 - 2a_1 + a_0)(b_2 - 2b_1 + b_0)(c_2 - c_0)$$

$$A_Q B_Q C_Q = \frac{1}{32\, r\, 3^{n-3}} (a_2 - 2a_1 + a_0)(b_2 - 2b_1 + b_0)(c_2 - 2c_1 + c_0)$$

Where, the yields will now be substituted for the treatment combinations with the indicated levels of $a, b, c,$ and multiplications will be repeated as before. In a similar idea, higher-level interaction can be defined. The sum of squares of these effects and interactions was computed using standard principles.

Assume that in a factorial experiment, three components A, B, and C are being investigated, each with three levels. In the 3^3 factorial designs, there are 27 treatment combinations. Each main effect has two degrees of freedom, each two-factor interaction has four degrees of freedom, and the three-factor interaction has eight degrees of freedom. If there are $'n'$ replicates, there are $n\, 3^3 - 1$ total degrees of freedom and $3^3(n-1)$ degrees of freedom for error. The sum of squares can be calculated using standard factorial design methods. Furthermore, if the factors are quantitative and each has one degree of freedom, the main effects can be partitioned into linear and quadratic components. Two-factor interactions can be decomposed into linear x linear, linear x quadratic, quadratic x linear, and quadratic x quadratic effects. Finally, the ABC three-factor interaction can be divided into eight single degrees of freedom components, such as linear x linear, linear x quadratic, quadratic x quadratic, and so on. Three-factor interaction isn't very useful in general. However one can separate the I and J components from the three-factor interaction in order to get two-factor interactions. $AB, AB^2, AC, AC^2, BC,$ and BC^2 are the two-factor interactions, and each component has two degrees of freedom. These components have no physical meaning. The $W, X, Y,$ and Z components of the three-factor interaction ABC are the four orthogonal two-degrees of freedom components of the interaction. The ABC interaction components are referred to as $AB^2C^2, AB^2C, ABC^2,$ and ABC, respectively. The I, J, W, X, Y, and Z components have no practical interpretations. The design is built using the notations listed below.

$$W(ABC) = AB^2C^2;\ X(ABC) = AB^2C;\ Y(ABC) = ABC^2 \text{ and } Z(ABC) = ABC$$

In the construction of fractional factorial design for the 3^3design, one can use any of the ABC interaction components, such as $ABC, AB^2C, ABC^2,$ and AB^2C^2. The 3^3 factorial confounded in three blocks of nine runs each. Thus, the possible components of interaction contrast as given below have 12 different one-third fractions.

$L = x_1 + x_2 + x_3 = u \ (mod\ 3)$ for ABC,
$L = x_1 + 2x_2 + x_3 = u \ (mod\ 3)$ for AB^2C
$L = x_1 + x_2 + 2x_3 = u \ (mod\ 3)$ for ABC^2
and $L = x_1 + 2x_2 + 2x_3 = u \ (mod\ 3)$ for AB^2C^2,
where $u = 0, 1\ or\ 2$,

If the number of significant factors in the full factorial design is more than the number of significant factors in the fractional factorial design, a reduced factorial design may be the better option. The purpose of this study is to create a reduced factorial design using only significant factors. It cannot be anticipated until the full factorial design is performed. If the experimenter wants that no information should be lost throughout the design and also there is no constraint to include all of the main and interaction factors except the non-significant factors then a reduced factorial design is more valuable and informative.

This study employed five alternative priors to obtain the Bayes Factors for full, fractional, and reduced factorial designs. Maruyama (2009), Wetzels et al. (2012), Wang and Sun (2014), and Wang et al. (2015) have all examined Bayes Factors conceptually. These priors are discussed by Vijayaragunathan and Srinivasan (2020, 2022) in their study of hierarchical two-way ANOVA models and factorial designs of factors each at two levels.

a). Zellner's g Prior

Prior to Bayesian hypothesis testing, Zellner's priors were most widely utilized. Many authors have previously examined this, including George and Foster (2016), Kass and Wasserman (1995), and others. By changing the value of g, one can evaluate two priors: (a) Unit Information Prior (UIP) if $g = n$, and (b) Risk Inflation Criterion (RIC) if $g = k^2$, where n=number of observations and k= number of predictors in the regression model. The Bayes Factor for the full model to the null model is

$$BF = (1 + g)^{(n-k-1)/2}[1 + g(1 - R^2)]^{-(n-1)/2} \quad (3)$$

b). Jeffreys-Zellner-Siow Prior

In the Jeffreys-Zellner-Siow (JZS), one estimates g from the data. This prior is a mixture of priors discussed by Liang et al. (2008). The following equation gives the Bayes Factor for the full model to the null model

$$BF = \frac{\left(\frac{n}{2}\right)^{\frac{1}{2}}}{\Gamma\left(\frac{1}{2}\right)} \int_0^\infty (1 + g)^{(n-k-1)/2} \, [1 + g\,(1 - R^2)]^{-(n-1)/2} \, g^{-3/2} \, e^{-n/2g} d \quad (4)$$

c). Hyper-g Prior

A family of prior distributions on g is known as the hyper- g prior. The term a range from 2 to 4, resulting in distinct hyper- g prior behaviour. For simplicity, one uses only two values: $a = 3$ and $a = 4$. The equation given below is the Bayes Factor for the full model to the null model.

$$BF = \frac{a-2}{2} \int_0^\infty (1 + g)^{\frac{n-k-1-a}{2}} \, [1 + g(1 - R^2)]^{-\frac{n-1}{2}} dg \quad (5)$$

3. Illustration

The present research considers the illustration from Montgomery (2019),

"A machine is used to fill 5-gallon metal containers with soft drink syrup. The variable of interest is the amount of syrup loss due to frothing. Three factors are thought to influence frothing: the nozzle design (A), the filling speed (B), and the operating pressure (C). Three nozzles, three filling speeds, and three pressures are chosen and two replicates of a 3^3 factorial experimental run".

The ANOVA output for syrup loss data is presented in Table 1 and it is observed that the filling speed B and the operating pressure C are statistically significant. The two-factor interactions, AB, AC^2, BC, BC^2, and three-factor interactions AB^2C^2 are also significant. It shows that the interaction effects are influenced by the soft drink syrup loss data even if the main effect, nozzle design A, is not significant in the full factorial design.

Table 1. ANOVA output for 3^3 full factorial design

Source of Variation	Sum Sq.	Df	Mean Sq.	F value	Pr(>F)	
factor(A)	994	2	497	1.165	0.327102	
factor(B)	61190	2	30595	71.735	1.57e-11	***
factor(C)	69105	2	34553	81.014	3.89e-12	***
factor(AB)	6174	2	3087	7.238	0.003042	**
factor(AB^2)	127	2	63	0.149	0.862592	
factor(AC)	635	2	318	0.745	0.484444	
factor(AC^2)	6879	2	3439	8.064	0.001795	**
factor(BC)	8581	2	4291	10.060	0.000543	***
factor(BC^2)	4273	2	2136	5.009	0.014116	*
factor(ABC)	19	2	9	0.022	0.978244	
factor(AB^2C)	222	2	111	0.260	0.772962	
factor(ABC^2)	584	2	292	0.685	0.512748	

factor(AB^2C^2)	3804	2	1902	4.460	0.021207	*
Residuals	11515	27	426			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The study proceeds to employ a 3^3 factorial design with three blocks of nine runs each. When the three-factor interaction AB^2C^2 will be confounded by blocks, let $L = x_1 + 2\,x_2 + 2x_3$ the defining contrast, then the treatment combinations belonging to the principal block are $000, 012, 101, 202, 021, 110, 122, 211, 220$.

Also other treatment combinations $200, 212, 001, 102, 221, 010, 022, 111, 120$ and $100, 112, 201, 002, 121, 210, 222, 011, 020$ are belonging to block 2 and 3 respectively.

Table 2. ANOVA output for 3^{3-1} fractional factorial design ($AB^2C^2\ at\ 0$)

Source of Variation	Sum Sq.	Df	Mean Sq.	F value	Pr(>F)	
factor(A)	2722	2	1361	3.091	0.095065	
factor(B)	9855	2	4928	11.192	0.003621	**
factor(C)	23211	2	11605	26.359	0.000173	***
factor(AB)	5567	2	2783	6.322	0.019279	*
Residuals	3962	9	440			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 3. ANOVA output for 3^{3-1} fractional factorial design ($AB^2C^2\ at\ 1$)

Source of Variation	Sum Sq.	Df	Mean Sq.	F value	Pr(>F)	
factor(A)	1519	2	760	1.120	0.367777	
factor(B)	22663	2	11332	16.708	0.000934	***
factor(C)	23644	2	11822	17.431	0.008030	***
factor(AB)	594	2	297	0.438	0.658385	***
Residuals	6104	9	678			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 4. ANOVA output for 3^{3-1} fractional factorial design $AB^2C^2\ at\ 2$

Source of Variation	Sum Sq.	Df	Mean Sq.	F value	Pr(>F)	
factor(A)	5352	2	2676	16.62	0.00095100	***
factor(B)	36134	2	18067	112.22	0.00000043	***
factor(C)	22599	2	11299	70.18	0.00000324	***
factor(AB)	4924	2	2461	15.28	0.00012770	**
Residuals	1449	9	161			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The ANOVA outputs for these one-third fractional factorial designs are shown in Tables 2 - 4. The main effects B and C, and the interaction effect AB are significant in the fractional factorial design when the factor AB^2C^2 at levels 0 and 1 (see Tables 2 and 3). But, three main effects and interaction AB are significant in the fractional factorial design when the factor AB^2C^2 at level 2 (see Table 4). The main effect A performs well when it interacts with another factor, a synergetic effect, in this experimentation. Moreover, all the fractional factorial designs do not provide the same results even if the factors are the same in the ANOVA output.

Unlike the main effect, nozzle design A significantly differs on the soft drink syrup only when the interaction AB^2C^2 at level 2. The main effects, filling speed B and operating pressure C, significantly differ in all levels of AB^2C^2. Also, the nozzle design interaction with different levels of filling speeds determined the loss of syrup impact in all three fractional factorial designs.

Table 5. ANOVA output for 3^3 reduced factorial design

Source of Variation	Sum Sq.	Df	Mean Sq.	F value	Pr(>F)	
factor(A)	6008	2	3004	9.942	0.000665	***
factor(B)	42010	2	21005	69.520	6.13e-11	***
factor(C)	50480	2	25240	83.537	8.53e-12	***
factor(AB)	6698	4	1675	5.542	0.002459	**
factor (BC)	10532	4	2633	8.715	0.000151	***
factor(AC^2)	1674	1	1674	5.540	0.026748	*
factor(AB^2C^2)	2798	1	2798	9.262	0.005440	**
Residuals	7554	25	302			

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

In the fractional factorial design, this study considered one-third of the observations from the full factorial design. Since one may lose potentially significant interaction effects in the fractional factorial designs, instead of ignoring factors the present study incorporated all the significant factors in the proposed reduced factorial design. . The ANOVA output for the reduced factorial design is presented in Table 5 and it is observed that the main effect A is highly significant in the reduced factorial design.

Table 6. Bayes Factor values for 3^3 full, fractional, and reduced factorial designs

Prior	Full Factorial Design	One-third Fractional Factorial Design for the three-factor interaction												Reduced Factorial Design
		ABC			AB^2C			ABC^2			AB^2C^2			
		0	1	2	0	1	2	0	1	2	0	1	2	
Zellner's g prior (UIP)	5.60	-0.34	-4.34	-1.12	-1.44	-0.18	-4.36	-0.56	0.001	-2.18	-1.57	-13.02	-10.11	4.58
Zellner's g prior (RIC)	4.67	-5.12	-10.88	-6.54	-7.05	-4.80	-17.83	-5.55	-4.42	-8.16	-7.26	-38.18	-32.08	4.04
Jeffreys-Zellner-Siow	6.80	-0.27	-2.41	-0.71	-0.88	-0.17	-2.56	-0.39	-0.06	-1.26	-0.94	-5.89	-5.36	5.17
Hyper-g prior (a=3)	7.03	0.15	-0.58	-0.03	-0.09	0.20	-0.41	0.10	0.25	-0.23	-0.12	-1.23	-1.19	5.27
Hyper-g prior (a=4)	6.83	0.22	-0.35	-0.08	-0.04	0.26	-0.07	0.18	0.29	-0.40	0.02	-0.95	-0.91	5.07

The main effect A is one of the highly significant factors in the reduced factorial design because the combination of other factor effects will influence the main effect A in the reduced factorial design. The ANOVA table for full, fractional and reduced factorial design provides slight variation in the results. Therefore, as proposed the study proceeded with the Bayesian Approach for quantifying the results in a better way. The Bayes Factor values for the full factorial, 12 different one-third fractional factorial, and reduced factorial designs are shown in Table 6. The factors support 5 to 7 times the model in a full factorial design. One may use any of the ABC interaction effects for further comparison.

The study used AB^2C^2 for computing the Bayes Factors for all factors from the one-third fractional factorial design. The results revealed that data support the null model for some cases "Poorly" and others "Strongly", which indicates that data does not support the fractional factorial design. In the fractional factorial design, priors like Zellner's g prior (UIP), Jeffrey-Zellner-Siow prior, and both Hyper-g priors offer more or less comparable results. However, the Bayes Factor values for Zellner's g prior (RIC) are nearly 3 to 6 times smaller than those for the other prior. Moreover, the Bayes Factors for reduced factorial design results are the same as the full factorial design. In order to generalize the findings, the study proceeded to determine the Bayes Factor values for three different factorial design variations. In the following section, the study compared the Bayes Factor values for these designs for simulated data.

4. Simulation Study

In order to get reliable results, dataset was simulated for the respective designs. Further, to calculate the values of the Bayes Factors for five priors, the simulation data was run over 10,000 iterations with an error variance of 1. The Bayes Factors were calculated for various datasets with error variances of 5, 25, and 50, respectively. The five prior Bayes Factors for these simulated data to the 3^3 full factorial, one-third fractional factorial, and reduced factorial designs are shown in Figures 1-5. The mean and standard deviation of Bayes Factor values for 3^3full, fractional and reduced factorial designs were presented in Table 7.

Table 7. Average (Standard Deviation) of 10000 Bayes Factor values to the simulated datasets of 3^3 full, 3^{3-1} fractional, and reduced factorial designs for five priors when the error variances are 1, 5, 25 and 50.

Error Variance (σ_e^2)	Zellner's g-prior (UIP)	Zellner's g-prior (RIC)	Jeffreys -Zellner -Siow	Hyper-g prior (a=3)	Hyper-g prior (a=4)
3^3 full factorial design					
1	5.12 (2.13)	1.17 (2.28)	6.43 (1.69)	6.74 (1.46)	6.54 (1.41)
5	5.07 (2.16)	1.12 (2.32)	6.39 (1.72)	6.70 (1.48)	6.51 (1.43)
25	3.77 (3.03)	0.56 (3.24)	5.36 (2.41)	5.86 (2.03)	5.71 (1.95)
50	1.78 (3.77)	0.15 (3.99)	3.79 (2.99)	4.63 (2.40)	4.53 (2.03)
3^{3-1} fractional factorial design (AB^2C^2 at 0)					
1	-1.11 (1.51)	-6.12 (2.72)	-0.64 (0.89)	0.04 (0.36)	0.13 (0.27)
5	-1.22 (1.51)	-6.35 (2.59)	-0.71 (0.86)	0.01 (0.34)	0.11 (0.26)
25	-2.95 (1.39)	-9.11 (1.92)	-1.67 (0.74)	-0.34 (0.23)	-0.17 (0.19)
50	-4.68 (1.42)	-11.28 (1.74)	-2.60 (0.78)	-0.61 (0.21)	-0.39 (0.18)
3^{3-1} fractional factorial design (AB^2C^2 at 1)					
1	-12.47 (1.43)	-36.99 (2.55)	-5.81 (0.32)	-1.23 (0.03)	-0.95 (0.03)
5	-12.57 (1.47)	-37.19 (2.47)	-5.83 (0.32)	-1.23 (0.03)	-0.95 (0.03)
25	-13.02 (0.85)	-39.21 (1.93)	-6.13 (0.36)	-1.26 (0.03)	0.09 (0.04)
50	-15.43 (1.36)	-41.28 (1.71)	-6.60 (0.44)	-1.30 (0.04)	-1.02 (0.04)
3^{3-1} fractional factorial design (AB^2C^2 at 2)					
1	-10.04 (0.62)	-31.31 (2.35)	-5.35 (0.09)	-1.19 (0.01)	-0.91 (0.01)
5	-10.20 (0.65)	-31.92 (2.24)	-5.38 (0.10)	-1.19 (0.01)	-0.92 (0.01)
25	-12.31 (1.05)	-36.89 (1.84)	-5.76 (0.22)	-1.22 (0.02)	-0.95 (0.02)
50	-14.59 (1.32)	-40.24 (1.75)	-6.34 (0.39)	-1.28 (0.04)	-0.99 (0.04)
3^3 reduced factorial design					
1	4.18 (1.65)	2.01 (1.82)	4.86 (1.31)	5.03 (1.11)	4.85 (1.06)
5	4.10 (1.73)	1.94 (1.73)	4.80 (1.37)	4.98 (1.16)	4.80 (1.10)
25	2.53 (2.54)	0.77 (2.77)	3.58 (1.99)	4.00 (1.62)	3.88 (1.54)
50	0.23 (3.15)	-1.22 (3.8)	1.79 (2.45)	2.69 (1.83)	2.65 (1.71)

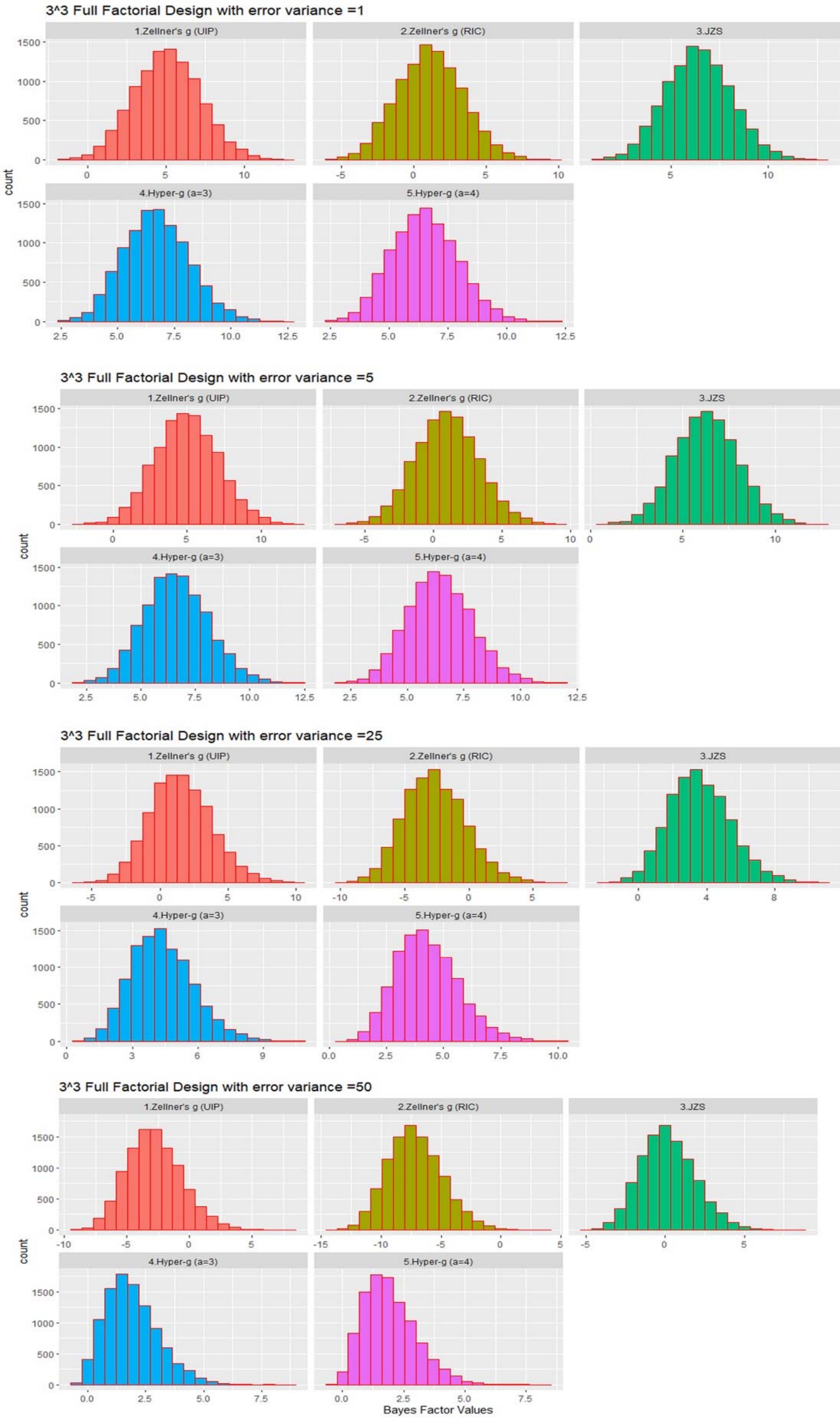

Figure 1. Bayes Factor values for 3^3full factorial design to the different simulation datasets

The results of 3^3 full factorial design are obtained from Figure 1, it may be seen that in Zellner's g (UIP) the distribution of the Bayes Factor ranges between 0 and 10, which means that the simulated dataset with an error variance of 1 for the 3^3 full factorial design data supports the model specified 0 to 10 times. The data support the model 0 to 5 times when an error variance is 5. The 3^3 full factorial design with error variance 25 provides mixed results that, out of 10000 iterations, approximately half of the iterations, the data supported the null model and the remaining half supported the specified model. Also, when the error variance is increased to 50, it provides mixed results.

For the Zellner's g prior (RIC) the data supports the model -5 to 7 times and -5 to 7 times when error variances are 1 and 5. Thus, half of the iteration result supports the null model and the remaining iterations support the full model. When error variance is 25, the data mostly supports the null model and sometimes supports the full model also. When error variance is 50, the data support the null model -12 to 0 times.

For the JZS the data supports the full factorial model 0 to 11 times when error variances are 1 and 5; the Bayes Factor values range between -1 and 9 when error variance is 25, almost the data supports the full model; when error variance is 50, the Bayes Factor values between -5 and 5 which mean that half of the result of the iteration supports the null model and remaining iterations supports the full model.

Both Hyper-g priors provide similar results such that the data supports the model 2 to 11 times, 2 to 11 times, 1 to 9 times and 0 to 5 times when error variances are 1, 5, 25, and 50 respectively. Thus, the two Hyper-g priors always support the 3^3 full factorial model.

The average of the Bayes Factor values for Zellner's g (UIP) prior are 5.12, 5.07, 3.77, and 1.78; for Zellner's g (RIC) prior are 1.17, 1.12, 0.56, and 0.15; for JZS prior are 6.43, 6.39, 5.36, and 3.79; Hyper-g (a=3) prior are 6.74, 6.70, 5.86, and 4.63; for Hyper-g (a=4) prior are 6.54, 6.51, 5.71, and 4.53 for the simulated dataset of 3^3 full factorial design with error variances of 1, 5, 25 and 50 respectively which are presented in Table 7.

The results of 3^{3-1} fractional factorial design (AB^2C^2 at 0) are obtained from Figure 2 and it may be seen that in Zellner's g (UIP) the distribution of the Bayes Factor for 3^{3-1} fractional factorial design (AB^2C^2 at 0) ranges between -5 and 2, -5 and 2, -7.5 and 0, and -9 and 0; for Zellner's g (RIC) prior ranges between -10 and 1, -10 and 1, -15 and -3, and -16 and -4; for JZS prior ranges between -3 and 2, -3 and 2, -4 and 0, and -5 and 0; both Hyper-g priors have almost same ranges between -1 and 1, -1 and 1, -1 and 0.5, and -1.2 and 0.3 when the error variance are 1, 5, 25, and 50 respectively.

The results of 3^{3-1} fractional factorial design (AB^2C^2 at 1) are obtained from Figure 3 and it may be seen that in Zellner's g (UIP) the distribution of the Bayes Factor for 3^{3-1} fractional factorial design (AB^2C^2 at 1) ranges between -16 and -9, -17 and -10, -17 and -11, and -18 and -11; for Zellner's g (RIC) prior ranges between -42 and -30, -45 and -30, -45 and -32, and -45 and -35; for JZS prior ranges between -7 and -4, -7 and -5, -7 and -5, and -8 and -5; both Hyper-g priors have almost same ranges between -1.3 and -1, -1.4 and -1.1, -1.4 and -1.2, and -1.4 and -1.2 when the error variance are 1, 5, 25, and 50 respectively.

The results of 3^{3-1} fractional factorial design (AB^2C^2 at 2) are obtained from Figure 4 and it may be seen that in Zellner's g (UIP) the distribution of the Bayes Factor for 3^{3-1} fractional factorial design (AB^2C^2 at 2) ranges between -12 and -9, -13 and -9, -15 and -9, and -18 and -10; for Zellner's g (RIC) prior ranges between -37 and -25, -37 and -25, -42 and -30, and -45 and -35; for JZS prior ranges between -5.75 and -5.25, -6 and -5, -7 and -5, and -8 and -5; for Hyper-g (a=3) prior ranges between -1.22 and -1.18, -1.23 and -1.17, -1.3 and -1.2, and -1.4 and -1.2; for Hyper-g (a=4) prior ranges between -1 and -0.9, -0.96 and -0.12, -1.05 and -0.9, and -1.1 and -0.9 when the error variance are 1, 5, 25, and 50 respectively.

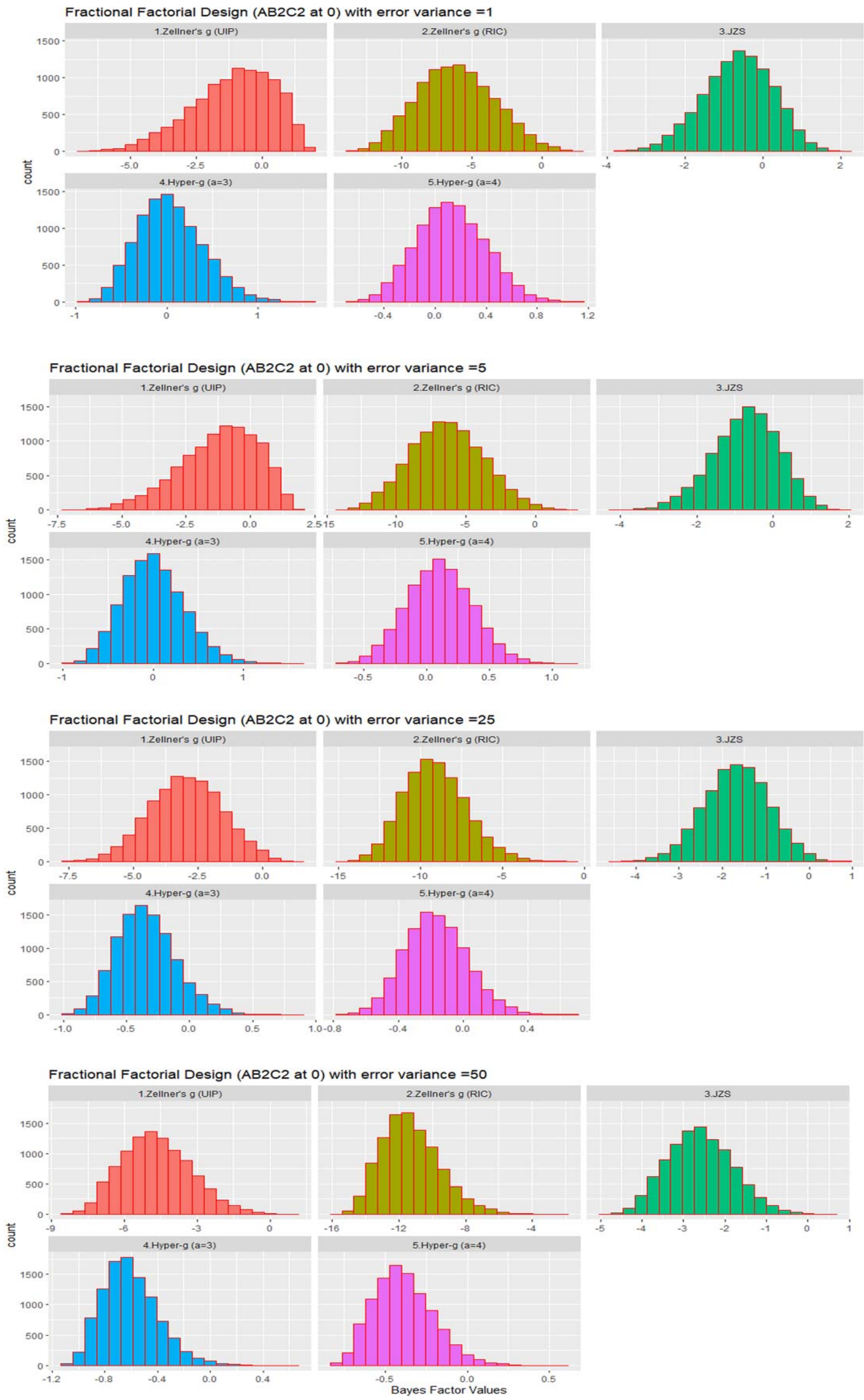

Figure 2. Bayes Factor values for 3^{3-1}fractional factorial design $(AB^2C^2\ at\ 0)$ to the different simulation datasets

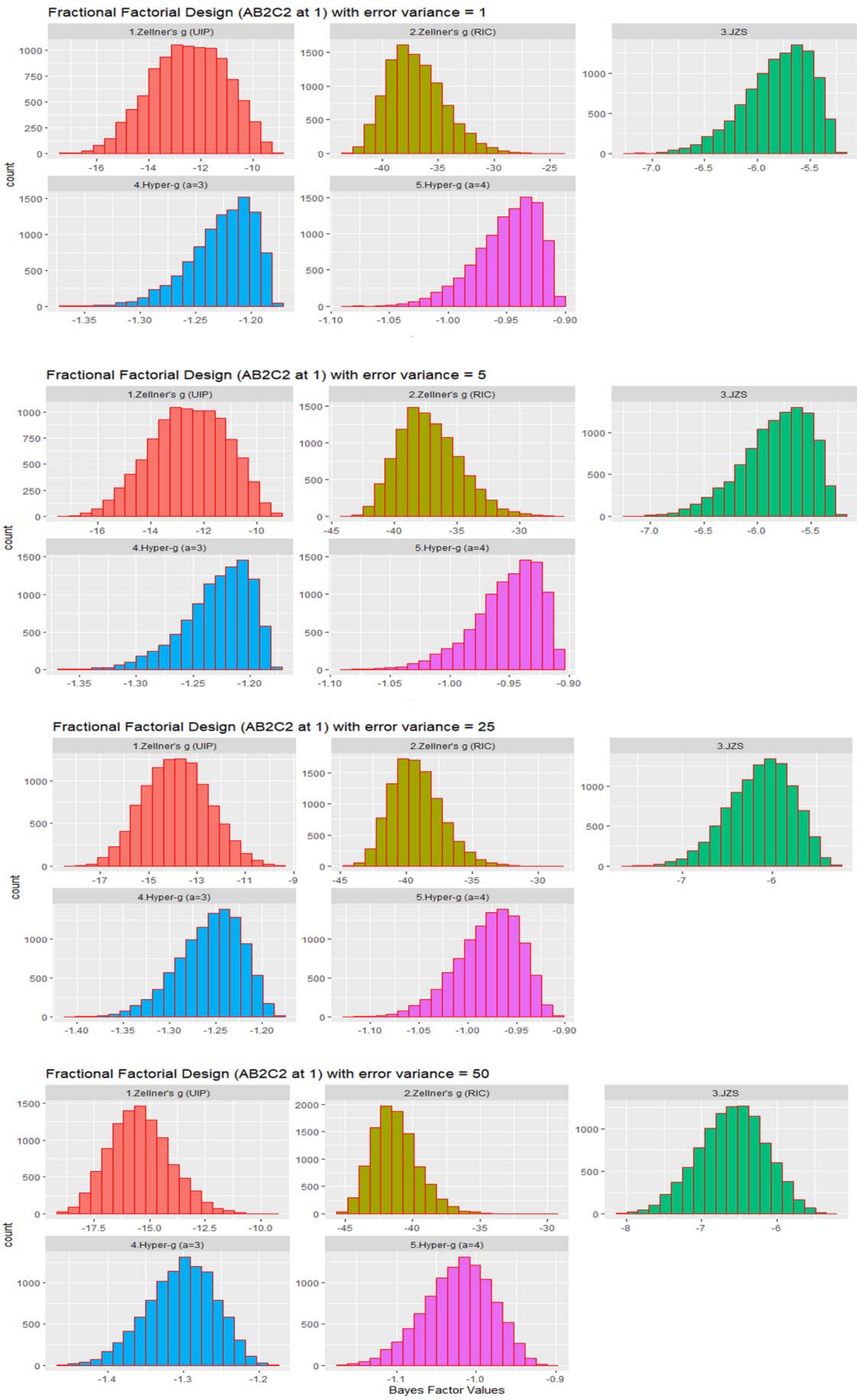

Figure 3. Bayes Factor values for 3^{3-1}fractional factorial design $(AB^2C^2\ at\ 1)$ to the different simulation datasets

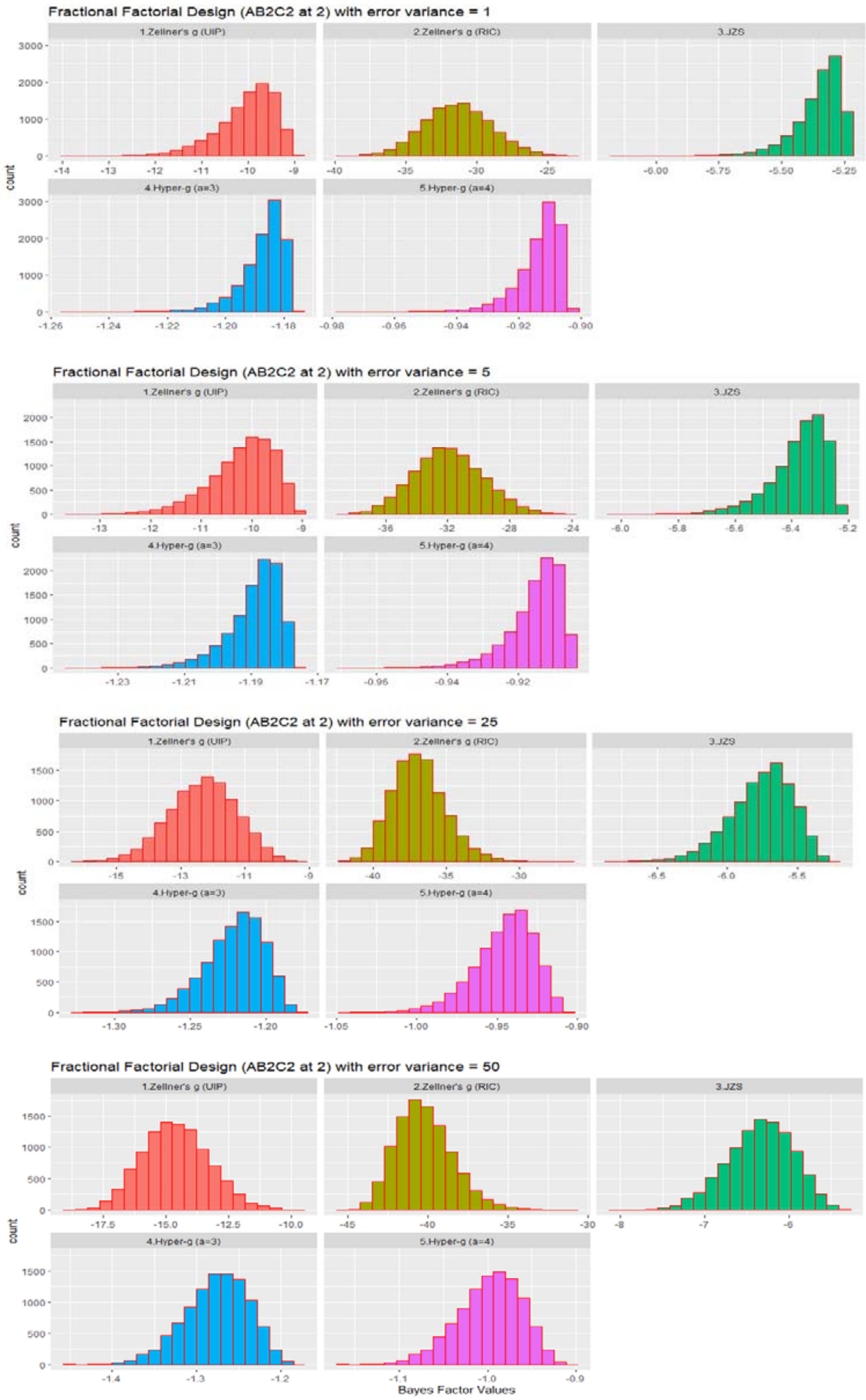

Figure 4. Bayes Factor values for 3^{3-1}fractional factorial design $(AB^2C^2\ at\ 2)$ to the different simulation datasets.

The average of the Bayes Factor values for Zellner's g (UIP), Zellner's g (RIC), Jeffreys-Zellner-Siow, Hyper-g (a=3) and Hyper-g (a=4) priors are presented in Table 7.

Thus, the distribution of the Bayes Factor values show that the simulated dataset almost "Decisively" supports all 3^{3-1} fractional factorial designs invariably in the present study. Particularly, the Bayes Factor values for both the Hyper-g priors have less variability than the other prior and these priors support "Poorly" the null model.

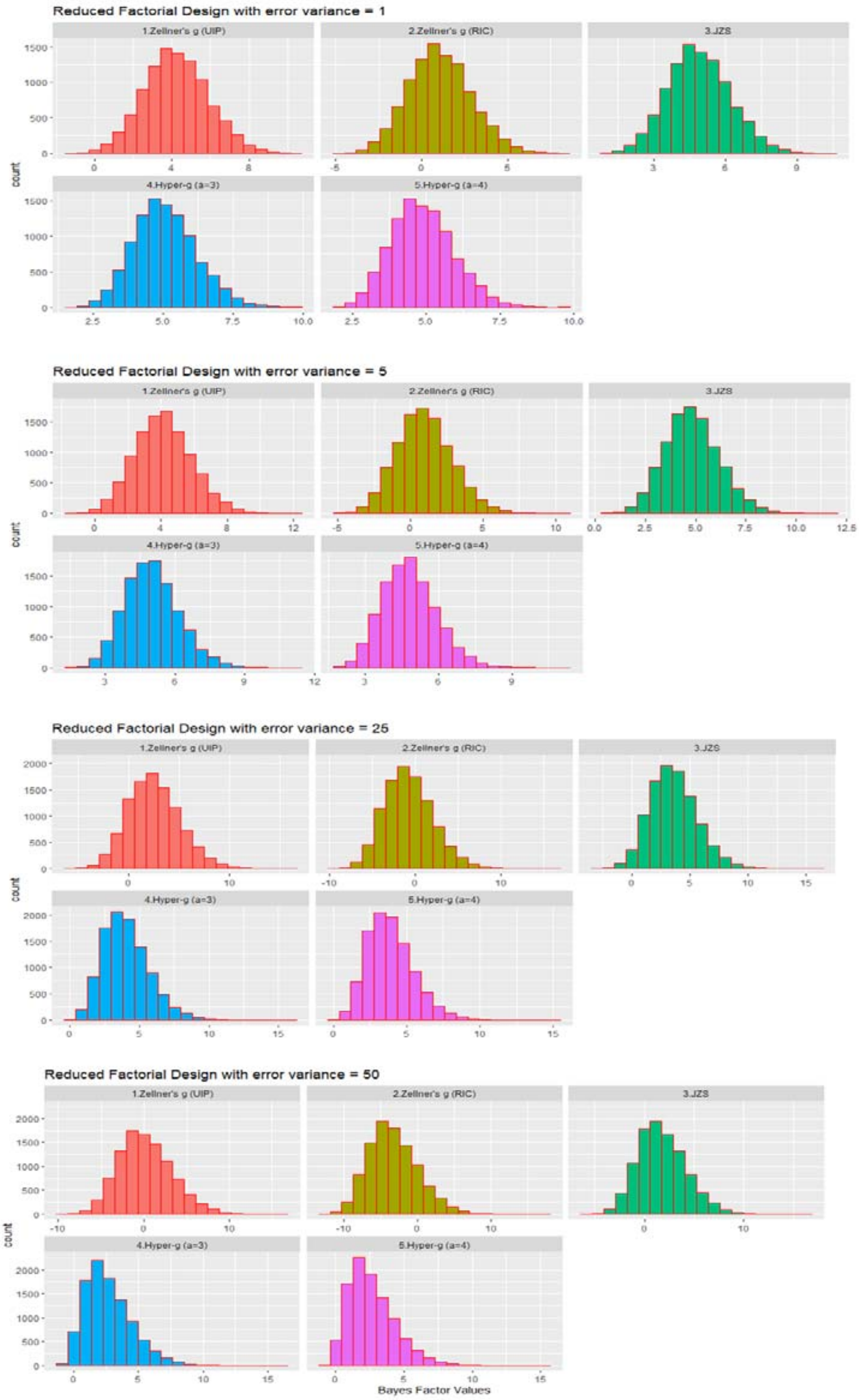

Figure 5. Bayes Factor values for 3^3 reduced factorial design to the different simulation datasets

From Figure 5, it may be seen that in Zellner's g (UIP) the distribution of the Bayes Factor ranges between 0 and 9, which means that the simulated dataset with an error variance of 1 for the 3^3 reduced factorial design data supports the model specified 0 to 9 times. The data support the model 0 to 12 times when an error variance is 5; the data support the model -1 to 10 times when an error variance is 25; The 3^3 reduced factorial design with an error variance of 50 provides mixed results that, the data support the model -10 to 10 times. Out of 10000 iterations, approximately half of the iterations, the data supported the null model and the remaining half supported the specified model. For the Zellner's g prior (RIC) the distribution of the Bayes Factor for 3^3 reduced factorial design ranges between -5 and 5, -5 and 10, -10 and 10, and -10 and 5; for JZS prior ranges between 4 and 9, 2 and 9, 0 and 10, and -2 and 10; both Hyper-g priors have almost same ranges between 2 and 8, 3 and 8, 0 and 10, and 0 and 10 when the error variance of 1, 5, 25, and 50 respectively. Thus, all priors except Zellner's g (RIC) are provided "Decisively" to support the reduced factorial model. Particularly, Zellner's g (RIC) prior gives mixed results that more or less half of the iterations supported the null model and the remaining half supported the reduced factorial model invariably among the different simulated datasets with various error variances.

The average of the Bayes Factor values for Zellner's g (UIP) prior are 4.18, 4.10, 2.53, and 0.23; for Zellner's g (RIC) prior are 2.0, 1.94, 0.77, and -1.22; for JZS prior are 4.86, 4.80, 3.58, and 1.79; Hyper-g (a=3) prior are 5.03, 4.98, 4.00, and 2.69; for Hyper-g (a=4) prior are 4.85, 4.80, 3.88, and 2.65 for the simulated dataset of 3^3 reduced factorial design with error variances of 1, 5, 25 and 50 respectively which are presented in Table 7.

The Bayes Factor values of different priors for the simulated datasets obtained the following results. In general, among the five priors, Zellner's g prior (RIC) produces a much smaller average of Bayes Factor values against the simulated datasets as compared with all other priors. This is because this prior has a high value of g, which is the square of the number of predictors in the respective model. The same results are obtained by RIC prior in all fractional factorial designs as well as the reduced factorial design. Particularly, all the one-third fractional factorial designs support the null model invariably. Furthermore, both the Hyper-g priors have a less standard deviation of the Bayes Factor values compared to all other priors. Finally, the Bayes Factor values for the reduced factorial design are almost close to the Bayes Factor values of full factorial design.

5. Summary and Conclusion

In this study, the investigation is basically on the use of Bayesian measures to determine the strength of the factors in the 3^3 factorial design. The Bayesian framework has been widely used in model selection, here the Bayesian principle was used to determine the intensity of the factors in 3^3 full, fractional, and reduced factorial models. Based on the classical factorial design analysis, it is found that the main effects B, and C; the first-order interaction AB, BC, AC^2 and BC^2; the second-order interaction AB^2C^2 are significant in the 3^3 full factorial design. The main effects B and C, and the interaction AB are significant in all three possible one-third fractional factorial designs. But all the factors are significant in fractional factorial design when the factor AB^2C^2 at level 2. All the factors are significant in 3^3 reduced factorial design. Furthermore, all the priors do not contribute the same Bayes Factor values to the respective factorial designs. Based on the Bayes Factor values, the factors supported 5 to 7 times the 3^3 full factorial design. In the simulation study, the Bayes Factor values for full and reduced factorial designs are positive which means that the data "Decisively" support the respective models. But, the Bayes Factors for fractional factorial designs are negative, which shows that the data does not support the fractional factorial designs. All these three one-third fractional factorial models do not produce similar results and also do not resemble the full factorial design in the results. In the proposed model, the Bayes Factor values in the reduced factorial design show "Strong" support for the model, the same as the full factorial design. Finally, it is concluded and generalized that the results based on the real-life application and simulated dataset, that the reduced factorial design is a more appropriate model for the full factorial design compared to the fractional factorial designs. Hence, the reduced factorial design is a better alternative to the full factorial design to check the strength or intensity of the factors. Furthermore, it is proposed to apply the same technique for more than three factors each at three levels of factorial designs, Analysis of the Covariance model, split-plot design, asymmetrical designs etc. to find the strength/intensity of the factors in the respective models in the future studies.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Author's Contributions

Authors contributed equally and approved the final manuscript.

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VALIDATING A DEEP LEARNING MODEL: THE NEXUS OF SELF-REGULATION STRATEGIES AND STUDENT WELL-BEING

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Abstract
This study was principally focused on verifying the suitability of the Deep Learning Strategies Questionnaire for Romanian academic environments and examining the interrelations among deep learning strategies, self-efficacy, subjective well-being, and academic performance. Utilizing a correlational-cross-sectional approach, the research involved 130 university students from various Romanian institutions. Data gathering was conducted via an extensive multidimensional questionnaire, which assessed components such as deep learning strategies, perceived self-efficacy, subjective well-being, and academic performance indicators. The methodological process included extensive collaboration with several higher education institutions for participant recruitment. The data analysis was carried out using JASP version 0.18.1, which combined descriptive and inferential statistical approaches with structural equation modeling. The research aimed to endorse a theoretical model that interconnects deep learning self-regulation strategies with elements like student well-being, perceived self-efficacy, and their collective influence on academic achievement. Notably, the exploratory factor analysis revealed the presence of five distinct factors, an enhancement from the four factors identified in the original model, providing a more comprehensive understanding of deep learning strategies. Furthermore, the hierarchical model related to deep learning strategies exhibited strong congruence. The study's instruments demonstrated robust reliability and validity, as evidenced by internal consistency metrics ranging from acceptable to high levels. This substantiates the efficacy of these scales in evaluating a broad range of learning strategies in an educational setting.

Keywords: *deep learning strategies questionnaire; self-regulated learning; student well-being; self-efficacy; academic performance*

1. Introduction

During a period marked by unparalleled challenges in higher education, exacerbated by the COVID-19 pandemic, the intricate aspects of student learning demand heightened attention and understanding. This research article contributes to the scholarly conversation in higher education, focusing on the intersection of self-regulated learning strategies with factors like self-efficacy and well-being, and their collective impact on academic performance. Central to this study is the investigation of the Deep Learning Strategies Model within the context of Romanian higher education.

The study is driven by two research objectives. The first objective is a validation of the Deep Learning Strategies Questionnaire, developed by Panadero et al. (2021), targeting Romanian students. This validation process is pivotal in verifying the questionnaire's suitability and effectiveness within a distinct cultural and educational milieu. The second objective is an in-depth analysis of how deep learning strategies are interwoven with three key dimensions essential to learning in higher education: self-efficacy, subjective well-being, and academic achievement.

1.1. Conceptualization of Self-regulated learning

In the realm of higher education, a substantial body of research has been dedicated to exploring not just the content of student learning, but also the tactics, the methodologies, and processes underlying it (Ellis * et al. 2004; Martínez Fernández et al. 2016; Shum et al. 2023; Trigwell, Prosser, and Waterhouse 1999; Vermunt and Vermetten 2004; Winne 2022). Historically, student learning has been conceptualized as a quantitative enhancement, predominantly centered around the accumulation of facts and procedural knowledge (Bransford, Brown, & Cocking, 2000). However, over the last thirty years, a paradigm shift has been observed in higher education, steering towards a more developmental understanding of learning. This shift is anchored in four fundamental elements: achievement goals, self-efficacy beliefs, self-regulation, and learning strategies, with a multitude of studies underscoring the intricate interplay among these components (Bouffard et al. 2005; Mega, Ronconi, and De Beni 2014; Neuville, Frenay, and Bourgeois 2007; Nückles, Hübner, and Renkl 2009; Panadero 2017). To align with this evolving perspective, our approach is grounded in the phenomenography tradition, particularly in the context of students' approaches to learning (SAL). According to this framework, students engage with learning tasks from either a surface or deep approach (Biggs, Kember, and Leung 2001), with more recent categorizations differentiating these approaches into fragmented and cohesive types (Ellis and Calvo 2006; Martínez Fernández et al. 2016). Initial efforts to define the concept of self-regulated learning (SRL) emerged in the late 1980s, spearheaded by scholars such as Zimmerman and Boekaerts. These early models of SRL identified various processes internal to the individual, highlighting the roles of (meta)cognitive, motivational, and emotional components in the regulation of learning. Self-regulated learning represents a proactive process wherein learners leverage their cognitive and physical capabilities to develop skills relevant to specific tasks (Smelser and Baltes 2001; Winne 2022). This approach encompasses a range of metacognitive, motivational, and behavioral activities initiated by individuals for the purpose of acquiring knowledge and skills (Bransen et al. 2022; Panadero 2017; Zimmerman 2000). These activities include, but are not limited to, setting goals, planning, employing various learning strategies, self-reinforcement, self-monitoring, and self-guidance. Furthermore, self-regulation in learning transcends mere cognitive actions; it also involves tangible behavioral actions. Examples of these actions are choosing, altering, or creating environments conducive to learning, as well as actively seeking social assistance when needed (Bransen et al. 2022; Mega, Ronconi, and De Beni 2014; Neuville, Frenay, and Bourgeois 2007). Importantly, self-regulation is not confined to solitary learning endeavors. It also encompasses collaborative learning scenarios, where achieving personal goals is contingent upon the concerted efforts of multiple individuals (Allal 2020; Bransen et al. 2022; Schunk 2011). This aspect of self-regulation highlights its adaptability to both individual and collective learning contexts.

1.2. Self-regulated learning strategies

In this paper, we explore various self-regulated learning strategies that enhance the learning process in higher education, focusing on explicit regulation, narrative and visual synthesis, in-depth information processing, and social adjustment in learning (Panadero 2017; Panadero et al. 2021).

Explicit Regulation Strategies. According to Panadero (2017), most models divide the regulation process into three cyclical phases: preparation (including task analysis and planning), performance execution (where the task is carried out while monitoring progress), and evaluation (where students assess their results). Each phase encompasses specific subprocesses of regulation. However, some of these are less "visible" and therefore harder to regulate. For instance, during the preparation phase, numerous motivational sub-processes occur in microseconds, often escaping students' conscious awareness. Consequently, our focus is on explicit strategies pertinent to each of these three main phases, which are comprehensive and clearly understood by students.

Narrative and Visual Synthesis Strategies. Cognitive psychology research asserts that students must process, understand, and store information in their memory to learn effectively (Dunlosky et al. 2013; Soderstrom and Bjork 2015). Students frequently employ visual strategies (like conceptual maps, tables) and summarization strategies (like formulating concise statements) to organize information into efficiently processable sequences (Moola et al. 2020; Weinstein, Sumeracki, and Caviglioli 2019). Studies have shown that using visual enhances retention, as these summarization and synthesis strategies are positively associated with self-regulated learning (Dunlosky et al. 2013; Jaeger and Fiorella 2023; Nesbit and Adesope 2006).

Deep Information Processing Strategies: In line with cognitive theory, both associating new information with existing structures and restructuring existing information are crucial for successful knowledge acquisition (Soderstrom and Bjork 2015). Learning strategies that activate these types of processes include relating new material to existing knowledge, applying learned concepts to real-life situations, and considering alternative solutions to real-world problems. Though cognitively demanding, these activities significantly enhance learning (Panadero, Jonsson, and Strijbos 2016; Panadero et al. 2021).

Social Regulation Strategies in Learning: Learning does not occur in isolation but rather within social contexts that influence regulation. Processes such as co-regulation and socially distributed regulation are common in classrooms, facilitated by teachers and peers (Allal 2020; Chan, Wan, and Ko 2019; Wu, Goh, and Mai 2023). Furthermore, group work has become a staple in classrooms, requiring students to collaborate effectively in ever-changing and complex scenarios. However, it's important to note that social interaction does not always yield positive learning outcomes, as evidenced by the work of Ndiku Makewa et al. (2014).

1.3. The current study: aims, research objectives and hypotheses

This paper is centered on fulfilling two primary research objectives (ROs):

RO1: The first objective is to examine the internal validity of the Deep Learning Strategies Questionnaire, as initially created by Panadero et al. (2021), specifically within the context of Romanian student populations.

RO2: The second objective involves investigating how deep learning strategies interact with three critical elements that influence learning in higher education. These elements are self-efficacy, subjective well-being, and academic performance. We have formulated specific hypotheses regarding these relationships (see **Figure 1**):

H1: Deep learning self-regulated learning strategies influence the perception of self-efficacy and, together, influences the subjective well-being of students.

H2: Deep learning self-regulated learning strategies influence the perception of self-efficacy and, together, influences the academic performance of students.

H3: Subjective well-being mediates the effect of self-regulation learning strategies on academic performance.

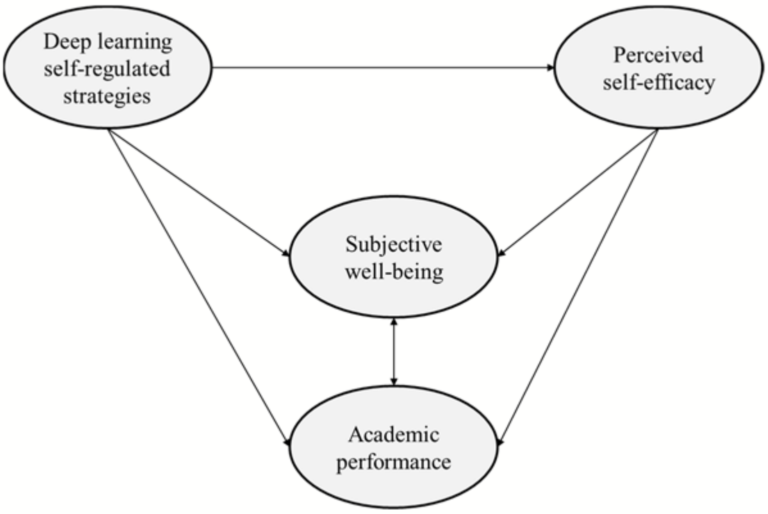

Figure 1. Theoretical model

Note: Developed by the authors

2. Methods

2.1. Study design and Participants

This quantitative study was conducted using a correlational-cross-sectional design. The study incorporated a sample of 130 university students selected based on availability criteria from four Romanian higher education institutions.

The composition of the study's participants primarily consisted of undergraduate students, accounting for 82%, while Master's students comprised the remaining 18%. Among the undergraduates, the breakdown was as follows: freshmen (44.6%), sophomores (22.3%), juniors (20.8%), and seniors (12.3%). The average age of the participants was 21.2 years

($M = 21.22, SD = 2.79$). In terms of gender distribution, females constituted the majority, representing 57% of the sample, which translates to 74 female participants.

2.2. Instruments

In order to encompass all the dimensions underlying the theoretical model, a multidimensional questionnaire was designed. It comprised: (1) sociodemographic items (items 1-6); (2) items dedicated to learning strategies (items 7-36); (3) items related to perceived self-efficacy (4 items); (4) the short version of the Oxford questionnaire for subjective happiness (8 items); academic performance measured as the annual average grade and semestrial average grade (2 items).

The Deep Learning Strategies Questionnaire, initially validated by Panadero et al. (2021), is structured in its final format to include 30 items. Respondents are prompted to answer using a 5-point Likert scale, spanning from 'Totally Disagree' to 'Totally Agree.' The questionnaire is designed to represent various types of strategies aimed at deep learning. It encompasses four distinct sections including S1 - Basic learning self-regulation strategies (8 items), S2- Visual elaboration and summarizing strategies (8 items), S3 - Deep information processing strategies (8 items), , and S4 - Social learning self-regulation strategies (6 items) (Panadero et al. 2021, 14). Cronbach's alpha coeficient ranged from 0.717 to 0.823 (see **Table 2**), indicating a good to very good internal consistency of each dimension included in the model.

Table 2. Deep learning strategies questionnaire. Values of Cronbach's alpha coefficients

Dimensions	Standardized Cronbach's alpha	Number of items
S1 – learning self-regulation strategies	0,752	8
S2 – visual elaboration and summarizing strategies	0,823	8
S3 – deep information processing strategies	0,821	8
S4 - social elaboration study strategies	0,717	6

Student Well-Being Scale. The measurement of student subjective well-being was conducted using eight items, constituting the abbreviated version of the Oxford Happiness Questionnaire (OHQ, $\alpha = 0.757$) (Hills and Argyle 2002). Each item among the eight was assessed on a 5-point Likert scale: 1 representing 'to a very little extent,' and progressing to 5, which stands for 'to a very large extent'

Self-efficacy for learning and performance scale. In order to measure the self-efficacy perception, the authors have formulated contextual five items to present the potentially anxiogenic situations, building upon the approach proposed by Bermejo-Toro et al. (Bermejo-Toro, Prieto-Ursúa, and Hernández 2016; Manasia, Pârvan, and Macovei 2020). Each item was associated with an item, formulating in a projective manner the capability to provide an adequate answer to the situation described. Each of the five items presenting potentially stressful situations was followed by the question: "When you find yourself in a situation similar to the one above, to what extent do you believe you can manage it?" ($\alpha = 0.720$) (Bermejo-Toro, Prieto-Ursúa, and Hernández 2016). The answer to the question was recorded on a 5-point Likert scale (1 = to a very little extent, 2 = to a little extent, 3= to a moderate extent, 4 = to a large extent, 5 = to a very large extent).

Academic performance was evaluated based on the average grade reported at the conclusion of the academic semester.

2.3. Procedure

In an effort to garner participants for the research, formal outreach was made to multiple higher educational institutions across the country. These institutions were requested to circulate the study invitation among their student body. This invitation encompassed a link for interested students to register their email addresses to obtain the questionnaire. To ensure the legitimacy of the email database, which accumulated to around 520 entries, the online platform email-checker.net was utilized. Following the validation, an invitation to partake in the survey was disseminated via e-mail, attaining a response rate of approximately 25%. Emphasizing the voluntary and anonymous nature of this study, participants were assured that no personal information gathered would be used for identification, and their email addresses would remain unassociated with the data collected. Non-consenting individuals were provided with the option to refrain from completing the survey. At the commencement of the survey and within the initial email containing the questionnaire link, subjects were informed about the research's nature, purpose, and estimated duration. The researchers' names and affiliations were openly disclosed for additional transparency. A statement within the questionnaire further affirmed the principle of voluntary participation, signifying that proceeding with the questionnaire symbolized their consensual involvement in the study. Participants were guaranteed exclusive use of their responses for research objectives, reinforcing the commitment to confidentiality and ethical research conduct.

2.4. Data Analysis

Analysis of the accumulated data was executed with JASP version 0.18.1. This analysis incorporated both descriptive and inferential statistics, along with structural equation modeling, ensuring a robust and comprehensive examination of the hypotheses. In this study, Principal Axis Factoring was utilized in an exploratory manner to identify the primary factors delineated by the variables and to condense the data to a more manageable set of variables. This factor analysis was independently conducted for each dimension encompassed in the theoretical model, namely subjective well-being, the four types of learning strategies, and self-efficacy. This procedure allowed for a reduction in variable number and a test of unidimensionality for each latent variable. Notwithstanding, given the separate and exploratory nature of these analyses, subsequent validation was deemed necessary. To validate the findings from the factor analysis and test the hypotheses, structural equation modeling was employed. In order to test the internal validity of the deep learning self-regulated strategies model, several models were tested. First, as a base, we used a structure in which the five dimensions of deep learning self-regulated strategies correlated with each other (Model SEM 1). Second, Model SEM 2 examined if the five primary factors related to the strategies served as indicators for a comprehensive construct termed Deep Learning Strategies. Thirdly, a mediation model was tested, according to which self-efficacy mediated the effect of deep self-regulated strategies on student subjective well-being and performance. Aligning with the guidelines proposed by Hooper et al. (2008), the computed normed/relative chi-square (X^2/df) was ensured to fall within the 2 to 5 range. Additional fit indices, such as RMSEA, GFI, AGFI, RFI, and TLI, were also calculated and scrutinized. Adhering to the recommendations by MacCallum et al. (1996), an RMSEA value within 0.05 to 0.08 was deemed indicative of a fair model fit, with more contemporary scholarly consensus advocating for values below 0.07 for an appropriate model fit. Concerning the GFI, AGFI, CFI, and TLI indices, values approaching the 0.95 threshold were sought as per Hooper et al. (2008), while values within the 0.85 to 0.95 range were considered to demonstrate a satisfactory model fit to the empirical data as per MacCallum et al. (1996). This study followed these prescribed criteria and acceptable thresholds to ensure the robustness and validity of the conducted analyses.

3. Results

The present paper aimed at validating a model of deep learning self-regulation strategies and test their relation with student well-being, perceived self-efficacy, and academic performance. Thus, the model assumes that perceived self-efficacy mediates the effect of self-regulation learning strategies and, together they influence student subjective well-being, this mediating the influence of the first two factors on academic performance. Complementarily, the direct influence of learning regulation strategies on academic performance will be tested.

3.1. Descriptives

Table 3 presents descriptive statistics (mean – M, standard deviation – SD, minimum – Min, and maximum – Max values) for the observed variables included in the statistical models.

The variables (statements) that manifested the highest mean values pertained to participants' inclination towards a comprehensive understanding and analysis of tasks, alongside a rigorous post-task completion review. Elevated mean scores were registered for variables epitomizing diverse facets of task comprehension and execution strategies. The variable S1_28, representing the practice of thoroughly reading and understanding instructions for assignments and exams, reported the uppermost mean value (M = 4.62, SD = 0.59).

Following closely were the variables S1_1 and S1_4, signifying in-depth task analysis (M = 4.38, SD = 0.74) and commitment to task visualization and follow-through (M = 4.32, SD = 0.86), respectively. Furthermore, the variable S1_20, indicating a post-task completion review to ascertain correctness (M = 4.25, SD = 0.99), also documented a high score, underscoring the significance participants attribute to self-evaluation and task reassessment.

Table 3. Descriptive statistics for the variables included in the statistical models (N=130)

Variables	Min	Max	M	SD	Skewness	Kurtosis
S1_1	2	5	4.38	.739	-.968	.330
S2_2	1	5	3.02	1.403	-.062	-1.330
S3_3	1	5	3.54	1.038	-.647	-.036
S1_4	1	5	4.32	.863	-1.543	2.805
S2_5_rev	1	5	4.30	1.001	-1.529	2.005
S3_6	1	5	3.85	1.053	-.902	.551
S4_7	1	5	3.44	1.329	-.489	-.947
S1_8	1	5	4.09	.944	-.861	.124
S2_9_rev	1	5	2.80	1.332	.174	-1.138
S3_10	1	5	4.01	.992	-1.128	1.347
S4_11	1	5	3.01	1.171	-.045	-.805
S1_12	1	5	3.84	1.055	-.958	.599
S2_13	1	5	3.99	1.165	-1.061	.320
S3_14	1	5	4.02	.906	-.919	.867
S4_15	1	5	3.27	1.316	-.366	-1.067
S1_16	1	5	3.83	1.005	-.816	.403
S2_17	1	5	3.81	1.201	-.956	.108
S3_18	1	5	3.94	.896	-.930	1.278

Variables	Min	Max	M	SD	Skewness	Kurtosis
S4_19	1	5	3.67	1.248	-.734	-.422
S1_20	1	5	4.25	.989	-1.442	1.704
S2_21_rev	1	5	3.11	1.163	-.153	-.688
S3_22	1	5	3.81	1.027	-.650	-.144
S4_23	1	5	3.30	1.211	-.252	-.952
S1_24	1	5	3.63	1.156	-.524	-.489
S2_25_rev	1	5	3.23	1.417	-.187	-1.312
S3_26	1	5	3.88	.881	-.655	.561
S4_27	1	5	3.44	1.264	-.433	-.845
S1_28	2	5	4.62	.589	-1.500	2.424
S2_29	1	5	3.19	1.333	-.127	-1.183
S3_30	1	5	4.11	.917	-1.135	1.273
AUTOEF1	2	5	3.68	.891	.019	-.848
AUTOEF2	1	5	3.27	.958	-.137	-.323
AUTOEF3	1	5	3.43	1.007	-.400	-.040
AUTOEF4	1	5	2.64	1.030	-.002	-.673
OHQ_1_rev	1	6	3.89	1.506	-.244	-.977
OHQ_2	1	6	3.86	1.435	-.315	-.727
OHQ_3	1	6	3.99	1.476	-.282	-.860
OHQ_4_rev	1	6	3.83	1.626	-.241	-1.085
OHQ_5	1	6	4.88	1.250	-1.224	1.308
OHQ_6	1	6	3.20	1.761	.124	-1.316
OHQ_7	1	6	2.88	1.332	.196	-.677
OHQ_8_rev	1	6	3.61	1.697	-.055	-1.294
PERF	5	10	8.55	0.87	-.704	1.428

Source: Developed by the authors based on the collected data

3.2. Results of the Factor Analyses

Deep Learning Strategies

At first, the factorability of the 30 items in the Deep learning strategies questionnaire was tested. Confirmatory factor analysis was performed to test the solution with four factors proposed by Panadero et al (Panadero et al. 2021). The Kaiser–Mayer–Olkin measure of sampling adequacy indicated that factor analysis is suitable for these data, with an overall MSA of $KMO = 0.82$. Most individual variables also have an MSA above 0.8, indicating good sampling adequacy. The Bartlett's test was statistically significant: $X^2(406, N = 130) = 1515.57, p < 0.001$, confirming that the data is suitable for factor analysis. The fit indices computed suggested that the model does not adequately fit the data. Most of the indices are below the commonly accepted thresholds for a good fit. The chi-square test for model adequacy was statistically significant, suggesting that the model does not fit the data well: $X^2(371, N = 130) = 652.371, p < 0.001$. Additional fit measures were computed. The adjusted chi-square value $X^2/2 = 326.165$ both indicates a poor fit to the observed data. Additionally, the low values of Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), 0.78 and 0.75 respectively, further reinforce this conclusion. These cumulative results signaled the imperative need for revising the current model or considering alternative models to enhance the fit to the data.

Therefore, we applied exploratory factor analysis (EFA), based on principal axis factoring (PAF) Similarly, the data were adequated for factor analysis: $KMO = 0.81$ and the Bartlett's test was statistically significant: X^2(348, N=130) = 524.8, p<0.001). The uniqueness values of the thirty variables ranged from 0.2 (S4_27) to 0.9 (S1_28). Several items (e.g., S2_5_neg, S2_9_neg, S1_28) have high uniqueness values, exceeding 0.70, suggesting that these items were not well-represented by the identified factors and might not fit well in the factor structure. In assessing the multivariate normality of the dataset, Mardia's tests for skewness and kurtosis were conducted. The test for multivariate skewness yielded a value of 298.12 with a chi-square statistic of $X^2 = 6310.39, (df = 4960, p < 0.001)$, indicating significant multivariate skewness in the dataset. The small sample skewness reported similar findings with a value of 298.12 and a chi-square statistic of $X^2 = 6469.15, (df = 4960, p < 0.001)$. Furthermore, the test for multivariate kurtosis exhibited a value of 1013.50 with a Z-value of 6.88 (p<0.001), denoting significant kurtosis. These results collectively suggest a violation of the assumption of multivariate normality in the dataset.

EFA was re-run after eliminating the ten items with uniqueness values over 0.7 from the analysis. A solution with 4 factors was revealed, indicating an improved and more reliable factor structure. **Table 4** presents the goodness of fit indices for the re-specified model of deep learning strategies.

Table 4. Goodness of fit indices of the deep learning strategies model, N = 130.

Model	X^2	df	**p**	X^2/df	$RMSEA$	TLI	**CFI**
Re-specified model of Deep learning strategies	115.96	100	0.13	1.15	0.03	0.96	0.98

Note: Developed by the authors

The factor structure presented in **Table 5** emerges as more robust and insightful for interpreting and assessing deep learning strategies. Each of the five factors possesses eigenvalues exceeding 1, collectively accounting for 53% of the variance in the deep learning strategies employed by students. This enhanced model promises improved reliability and validity in exploring and understanding the depth of learning strategies in educational contexts.

Table 5. Summary factor analysis and eigenvalues

Item	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Uniqueness**	**Eigenvalues**
S2_25_neg	0.8					0.39	5.84
S2_29	0.7					0.42	
S2_2	0.69					0.47	
S2_21_neg	0.67					0.51	
S2_17	0.66					0.4	
S3_10		0.84				0.26	2.29
S3_18		0.71				0.47	
S3_6		0.53				0.53	
S4_11		0.46				0.6	
S3_14		0.45				0.54	
S4_27			0.92			0.16	2.07
S4_7			0.76			0.43	
S4_15			0.58			0.6	
S1_4				0.82		0.35	1.32
S1_1				0.46		0.69	
S1_12				0.42		0.58	
S1_20				0.40		0.69	
S3_22					0.97	0	1.12
S3_26					0.5	0.63	
S3_3					0.5	0.66	

Note. Applied rotation method is oblimin.

A parallel analysis was conducted using characteristics identical to those of the dataset. This analysis indicated that retention should be limited to only three factors, where the eigenvalues exceeded those of factors generated randomly, as suggested by Yaguarema et al. (2022).

Perceived self-efficacy

Similar to the way in which we proceeded for testing the deep learning self-regulation strategies model, EFA with PAF analyses were also conducted for the items associated with the self-efficacy dimension. The collected data are suitable for factorial analysis: $KMO = 0.81$, and Bartlett's test is statistically significant ($BST = 218.77, df = 6, p < 0.001$). The inter-item correlations are of low to medium intensity, statistically significant. The uniqueness scores have values between 0.30 and 0.58. A varimax rotation was used to simplify the factor loadings. Overall, the fit indices in **Table 6** suggest that the model fits the data very well.

Table 6. Goodness of fit indices. Self-efficacy, N = 130.

Model	X^2	df	p	X^2/df	$RMSEA$	TLI	CFI
Self-efficacy	3.20	5	0.67	0.64	0.00	0.98	1.00

Note: Developed by the authors

A single factor was extracted. Thus, all four items, viewed as observed variables, load on a single factor, whose eigenvalue is greater than 1 and explains approximately 59% of the variation of the latent variable self-efficacy (

Table 7). The resulting factorial score (calculated by the regression method) was saved and was used for additional analyses to substantiate the factorial model of students' academic performance.

Table 7. Summary factor analysis and eigenvalues

Factor	Item	Factor loading	Uniqueness	%Variance Explained Cumulative	Eigenvalues
Factor :	AUTOEF2	0.84	0.3	0.59	2.76
Perceived self-efficacy	AUTOEF1	0.82	0.33		
	AUTOEF3	0.76	0.42		
	AUTOEF4	0.65	0.58		

Note: Applied rotation method is varimax.

Subjective well-being

The factor structure of Subjective Well-Being has been valuated using EFA with PAF as the extraction method. The data are relatively suitable for factor analysis, as indicated by a KMO measure of sampling adequacy of 0.77 and a statistically significant Bartlett's Test of Sphericity ($BST = 295.17, df = 28, p < 0.001$). Despite the range of uniqueness scores from 0.21 to 0.95, all items within the model have been retained due to their theoretical relevance to the construct of subjective well-being. This decision underscores the pivotal role of theoretical grounding in model building, ensuring that each item's conceptual contribution is carefully weighed alongside statistical metrics. The use of Varimax rotation further simplifies the factor loadings, contributing to an overall good model fit as suggested by the fit indices in **Table 8**.

However, it is noteworthy that the RMSEA of 0.10 is slightly higher than the ideal threshold, pointing to a potential avenue for enhancing the model fit. Despite the low p-value (<0.001) indicating a discrepancy between the model and the data, the $X^2/df = 2.27$,

$TLI = 0.87$, and $CFI = 0.90$ are within an acceptable range, highlighting a reasonable fit of the model.

Table 8. Goodness of fit indices. Subjective well-being, N = 130.

Model	X^2	df	p	X^2/df	$RMSEA$	TLI	CFI
Subjective well-being	45.45	20	<0.001	2.27	0.10	0.87	0.90

Note: Developed by the authors

Table 9 displays the summary factor analysis and eigenvalues. A single factor has been extracted, with an eigenvalue greater than one, explaining approximately 34% of the variance of the latent variable, subjective well-being. The ensuing factorial score, computed via the regression method, is earmarked for further analyses to substantiate the factorial model of students' academic performance.

Table 9. Summary factor analysis and eigenvalues

Factor	Item	Factor loading	Uniqueness	%Variance Explained Cumulative	Eigenvalues
Factor : Subjective well-being	OHQ_2	0.89	0.21	0.34	3.21
	OHQ_3	0.78	0.39		
	OHQ_4_rev	0.67	0.55		
	OHQ_1_rev	0.6	0.64		
	OHQ_7	0.42	0.82		
	OHQ_5		0.95		
	OHQ_6		0.9		
	OHQ_8_rev		0.84		

Note: Applied rotation method is varimax.

3.3. Results of the SEM analyses

Model SEM 1 – Intercorrelated factors of the deep learning strategies model

We present the first model in Figure 3. The data were run through JASP with Diagonally Weighted Least Squares estimation, and the results (**Table 10**) indicate an acceptable fit. The skewness and kurtosis statistics indicated a violation of the univariate normality. Thus, the data were bootstrapped with 1000 draws at the 95% bias-corrected confidence level.

The χ^2 value is 218.76 with 179 degrees of freedom, and the p-value is 0.02. Typically, a non-significant p-value is desired, indicating a good fit of the model. TLI and CFI indices are close to 1, indicating an excellent fit to the data. The RMSEA value is 0.04, with a 90% CI between 0.02 and 0.06 and a p-value of 0.75. The GFI is 0.97, also indicating a good fit. The residual variance estimates are quite varied, ranging from as low as 0.09 to as high as 0.70. Most of the estimates are around the 0.4 to 0.6 range, which is a moderate level of residual variance.

Table 10. Goodness of fit indices Model 1, N = 130

Model	X^2	df	p	X^2/df	$RMSEA$	TLI	CFI	GFI
Model SEM 1 – Intercorrelated factors of the deep learning strategies model	218.76	179	0.02	1.22	0.04	0.99	0.99	0.97

Note: Developed by the authors

All the covariances between the factors were statistically significant. The p-values are less than 0.001 for most factor pairs, strongly affirming the statistical significance of the covariances. The exception is the covariance between Factor 4 and Factor 5, though it is still significant with a p-value of $p = 1.93 * 10^{-3}$. The covariances between certain pairs of factors (for example, Factor 1 and Factor 5) are comparatively higher, signaling a stronger relationship. Conversely, pairs like Factor 4 and Factor 5 exhibit a weaker relationship.

Table 11. Model SEM 1. Factor covariances

					95% Confidence Interval		Standardized		
Variables	**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**	**All**	**LV**	**Endo**
Factor1 - Factor2	0.29	0.02	11.96	< .001	0.17	0.39	0.50	0.50	0.50
Factor1 - Factor3	0.28	0.03	10.38	< .001	0.12	0.41	0.60	0.60	0.60
Factor1 - Factor4	0.16	0.03	5.61	< .001	-0.03	0.32	0.23	0.23	0.23
Factor1 - Factor5	0.41	0.03	12.39	< .001	0.24	0.52	0.65	0.65	0.65
Factor2 - Factor3	0.27	0.03	9.54	< .001	0.15	0.38	0.54	0.54	0.54
Factor2 - Factor4	0.20	0.03	6.14	< .001	0.01	0.35	0.27	0.27	0.27
Factor2 - Factor5	0.26	0.03	7.81	< .001	0.07	0.38	0.38	0.38	0.38
Factor3 - Factor4	0.19	0.03	5.41	< .001	-0.02	0.33	0.31	0.31	0.31
Factor3 - Factor5	0.26	0.04	7.26	< .001	0.07	0.39	0.47	0.47	0.47
Factor4 - Factor5	0.14	0.04	3.10	1.93×10^{-3}	-0.08	0.34	0.16	0.16	0.16

Note: Developed by the authors

Model SEM 2 – Hierarchical model of the deep learning strategies

The objective of this analysis was to examine if the five primary factors related to the strategies serve as indicators for a comprehensive construct termed Deep Learning Strategies. As depicted in **Table 12**, the goodness of fit for this model is comparable to that of Model 1. Even though the Chi-square was significant, other fit indices such as the ratio of X^2/df, the RMSEA, TLI, and CFI were comfortably within the acceptable thresholds, permitting the acceptance of this model.

Table 12. Goodness of fit indices Model 2 (N=130)

Model	X^2	df	**p**	X^2/df	$RMSEA$	TLI	**CFI**	**GFI**
Model SEM 2 – Hierarchical model of the deep learning strategies	212.74	165	7.22×10^{-3}	1.28	0.05	0.99	0.99	0.97

Note: Developed by the authors

All relationships between the latent variables (

Table ***13***) and their indicators are statistically significant $p < 0.001$. The estimates of these relationships vary, with values ranging from 0.53 to 1.13. The 95% confidence intervals for each relationship further corroborate these findings, with none encompassing zero, reinforcing the reliability and consistency of the path coefficients. The standardized estimates, ranging from 0.33 to 0.97, provide additional affirmation of the varying strengths in relationships between latent variables and indicators.

Table 13. *Second-order factor loadings*

Factor	Indicator	Estimate	Std. Error	z-value	p	95% Confidence Interval Lower	Upper	Std. Est. (all)
Deep learning strategies	Factor 1	0.64	0.12	5.41	< .001	0.41	0.87	0.54
	Factor 2	1.98	0.55	3.59	< .001	0.90	3.06	0.89
	Factor 3	0.32	0.11	2.95	3.15×10^{-3}	0.11	0.53	0.30
	Factor 4	1.53	0.34	4.53	< .001	0.87	2.19	0.84
	Factor 5	1.56	0.39	3.98	< .001	0.79	2.33	0.84

Factor loadings

Factor	Indicator	Estimate	Std. Error	z-value	p	95% Confidence Interval Lower	Upper	Std. Est. (all)
Factor 1	S2_25_neg	0.67	0.05	14.04	< .001	0.58	0.77	0.80
	S2_29	0.67	0.05	13.24	< .001	0.57	0.77	0.80
	S2_2	0.65	0.05	12.05	< .001	0.54	0.75	0.77
	S2_21_neg	0.58	0.05	10.89	< .001	0.48	0.68	0.69
	S2_17	0.67	0.05	13.61	< .001	0.57	0.77	0.80
Factor 2	S3_10	0.34	0.08	4.50	< .001	0.19	0.49	0.76
	S3_18	0.33	0.07	4.43	< .001	0.18	0.48	0.73
	S3_6	0.33	0.08	4.32	< .001	0.18	0.49	0.74
	S4_11	0.25	0.06	3.99	< .001	0.13	0.38	0.56
	S3_14	0.34	0.08	4.52	< .001	0.19	0.49	0.76
Factor 3	S4_27	0.91	0.07	13.62	< .001	0.78	1.04	0.95
	S4_7	0.71	0.05	13.69	< .001	0.61	0.81	0.74
	S4_15	0.62	0.06	11.20	< .001	0.52	0.73	0.65
Factor 4	S1_4	0.29	0.06	4.77	< .001	0.17	0.41	0.53
	S1_1	0.35	0.08	4.47	< .001	0.20	0.50	0.64
	S1_12	0.40	0.07	5.69	< .001	0.26	0.53	0.73
	S1_20	0.34	0.07	4.94	< .001	0.21	0.48	0.62
Factor 5	S3_22	0.42	0.08	5.39	< .001	0.27	0.57	0.78
	S3_26	0.37	0.06	6.29	< .001	0.26	0.49	0.70
	S3_3	0.35	0.08	4.32	< .001	0.19	0.51	0.65

Note: Developed by the authors

Reliability

In addition to evaluating fit indices, an analytical diagnosis of the models was performed. The summary of Cronbach's alpha, McDonald ω, and Average Variance Extracted (AVE) is presented in Table 13. Each scale reflects a range from acceptable to high internal consistency. Despite some scales having AVEs marginally below the 0.5 threshold, hinting at potential concerns regarding their construct validity, the majority display robust metrics. This underscores their reliability and validity in assessing diverse learning strategies.

Table 14. Reliability of the Deep Learning Strategies Questionnaire

Scale	Cronbach's alpha	McDonald ω	AVE
Deep learning strategies questionnaire (20 items)	0.86	0.84	0.52
Visual elaboration and summarizing strategies	0.85	0.84	0.52
Integrative Reflective Learning	0.79	0.80	0.51

Strategies			
Social learning self-regulation strategies	0.80	0.80	0.63
Basic learning self-regulation strategies	0.68	0.68	0.40
Practical Application and Critical Analysis Strategies	0.73	0.70	0.50

Note: Developed by the authors

Mediation analysis

In the current study, a mediation analysis was conducted to examine the indirect effects of deep learning self-regulated strategies (DEEP) on students' average grades (AVEG) and subjective well-being (WB), through perceived self-efficacy.
presents the path diagram.

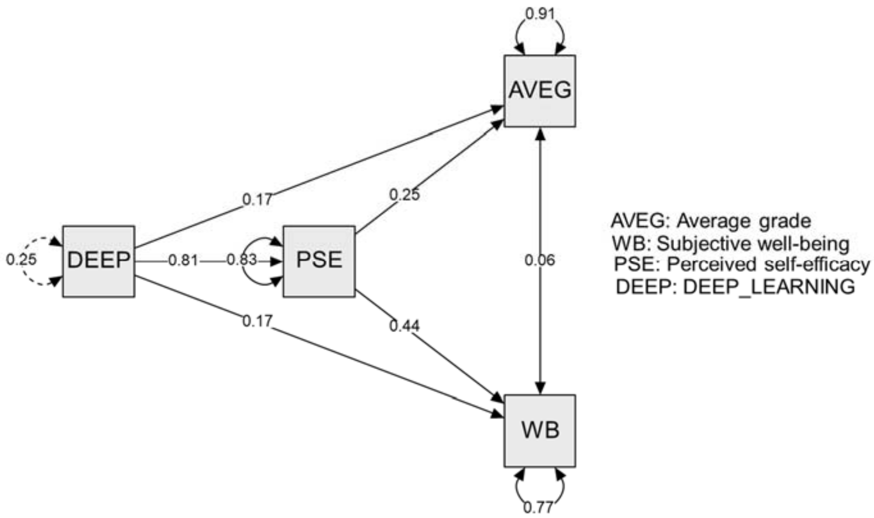

Figure 2. Path diagram
Note: Developed by the authors in JASP 0.18.1

The path diagram provided delineates the relationships among four key constructs: DEEP (Deep Learning), PSE (Perceived Self-Efficacy), AVEG (Average Grade), and WB (Subjective Well-Being). The model encapsulates both direct and indirect pathways through which these constructs are hypothesized to interact.

In the proposed model, deep learning is posited as a foundational construct that exerts a significant direct effect on Perceived Self-Efficacy (PSE), indicated by a substantial path coefficient of 0.83. This suggests a strong positive relationship where deeper engagement in learning is associated with increased self-efficacy. Additionally, PSE shows positive direct effects on both Average Grade (AVEG) and Subjective Well-Being (WB), with path coefficients of 0.25 and 0.44, respectively. These paths indicate that students with higher self-efficacy are likely to achieve better grades and report higher well-being.

Moreover, the model highlights the mediating role of PSE between DEEP Learning and the outcomes of AVEG and WB, as reflected by the indirect effects with path coefficients of 0.17 for both outcomes. This mediation suggests that the influence of deep learning on grades and well-being is partially channeled through self-efficacy beliefs.

Notably, AVEG is also shown to have a strong direct effect on subjective well-being with a path coefficient of 0.91. This implies that academic performance is a critical determinant of students' subjective well-being, potentially overshadowing other factors.
The variance explained in the model for DEEP Learning is relatively low (0.25), indicating that other factors not included in the model might contribute to the development of deep learning approaches. In contrast, the model accounts for a considerable proportion of the variance in Subjective Well-Being (0.77), suggesting that the included constructs are significant contributors to students' well-being.

4. Discussion and conclusions

This study aimed to evaluate the internal validity of the Deep Learning Self-Regulation Strategies Questionnaire, originally developed by Panadero et al. (2021). Additionally, it sought to examine the relationship between deep learning strategies and student academic performance, perceived self-efficacy, and subjective well-being.

Initially, the factorability of the 30 items in the Deep Learning Strategies Questionnaire was assessed and deemed satisfactory. Consequently, Confirmatory Factor Analysis (CFA) was employed to evaluate the model structure initially proposed by Panadero et al. (2021). However, the original model did not demonstrate acceptable fit, necessitating a re-specification. Subsequently, a five-factor solution emerged, identifying the following learning strategies: *Visual Elaboration and Summarizing Strategies, Integrative Reflective Learning Strategies, Social Learning Self-Regulation Strategies, Basic Learning Self-Regulation Strategies, and Practical Application and Critical Analysis Strategies*. Therefore, the model proposed in this study suggests a revised factor structure with five factors, in contrast to the four-factor structure originally reported by Panadero et al. (2021). It is important to note that the sequence in which the factors are presented does not represent the progressive stages of the self-regulated learning process. Rather, this order corresponds to the manner in which the factors were extracted during the analysis. For the sake of maintaining consistency in reporting our findings, we have chosen to retain this original order.

The first factor in our model, termed *Visual Elaboration and Summarizing Strategies*, encompasses strategies utilized for visually processing learning materials. This factor aligns with findings from Panadero et al. (2021) and Yaguarema et al. (2022), corroborating its relevance in educational research. Substantial empirical support underscores the effectiveness of these strategies, as highlighted in studies by Jaeger & Fiorella (2023) and Weinstein et al. (2019). The specific items that loaded onto this factor (namely, items 2, 17, 21, 25, and 29) are directly linked to both visual and verbal elaborations. These include activities such as creating graphs, diagrams, concept maps, charts, tables, and summaries, all of which are integral to this factor.

The second factor we identified referred to *integrative reflective learning strategies*. Items such as relating study material to what is already known, and connecting class content to personal ideas (i.e., items 10, 6, 18, 14), demonstrate an integrative approach to learning. This suggests a deep processing of information, where new knowledge is integrated with existing cognitive structures. Reflective and integrative learning is a progressive process influenced by various factors and student experiences, both within and beyond the classroom setting, throughout their university education (Awang-Hashim et al. 2022; Bransen et al. 2022; Youngerman 2018). Research in the field of deep learning indicates that educators and institutions emphasizing the cultivation of reflective and integrative learning skills tend to offer students opportunities to explore complex topics extensively. This approach includes encouraging students to engage in profound reflection, scrutinize and assess their own viewpoints, juxtapose them with differing perspectives, and ultimately synthesize disparate information segments into a cohesive and meaningful interpretation (Awang-Hashim et al. 2022; Barton and Ryan 2014). Barber (2012) defines reflective and integrative learning as "the capacity to coherently connect, apply, and synthesize information from various contexts and viewpoints, utilizing these newfound insights across multiple situations" (p. 593). This factor, primarily associated with the concept of integrative learning, also incorporates an element related to co-regulatory strategies (Bransen et al. 2022), as evidenced by item 11.

The third factor, *Social Learning Self-Regulation Strategies*, captures the essence of active engagement with peers in the learning process, both through discussion of study topics and seeking feedback on task performance, as suggested by Panadero et al. (2021), and Yagurema et al. (2022). Items 7, 15, and 27 pertain to interactions with students in a learning context. These items potentially represent the social dimensions of self-regulated learning, encompassing scenarios where students seek support (external regulation), exercise self-regulation, influence the regulation of others, and engage in group-based regulation during tasks (Bransen et al. 2022; McNamara 2011; Mega, Ronconi, and De Beni 2014; Panadero 2017; Panadero, Jonsson, and Strijbos 2016).

The fourth factor, Basic Learning Self-Regulation Strategies, identifies a series of fundamental steps that learners undertake to effectively manage and assess their learning process (Zimmerman 2000), involving metacognitive planning, monitoring, and evaluation (Jaeger and Fiorella 2023; Winne 2022). Firstly, it involves an analysis of the task at hand. This is where learners delve deeply into the requirements and objectives of the task, ensuring they have a clear understanding of what is expected of them. Subsequently, learners engage in a process of visualization and implementation. Moreover, the factor includes the utilization of self-assessment tools provided by educators. This aspect underscores the value of reflection and self-evaluation in the learning process (Kostons, van Gog, and Paas 2012; Panadero, Brown, and Strijbos 2016; Panadero, Jonsson, and Strijbos 2016). Finally, the factor is rounded out with a post-task review. This is where learners reflect on their completed work, analyzing it critically to ascertain if it meets the set standards and objectives. While this factor was included in the initial model (Panadero et al. 2021; Yaguarema, Zambrano R., and Salavarría 2022), subsequent reliability analysis revealed suboptimal indices $Cronbach's\ \alpha = 0.68; \omega = 0.68: AVE = 0.40$.

Finally, the fifth factor, *Practical Application and Critical Analysis Strategies,* encompassed items related to deep information processing strategies (i.e., 3, 22, 26), aligned with the concrete processing strategies in the learning patterns model (Gijbels et al. 2013; Martínez-Fernández and Vermunt 2015; Shum et al. 2023; Vanthournout et al. 2013; Vermunt and Donche 2017; Vermunt and Vermetten 2004).

The findings of our study indicate a requirement for a more refined approach to deep information processing learning strategies. This approach should specifically encompass the nuances of integrative learning and concrete processing strategies. Furthermore, the study's results are derived from a condensed version of the Deep Learning Strategies Questionnaire (Panadero et al. 2021). This reduction involved the exclusion of 10 items from the analysis, attributed to their high uniqueness values.

The second research objective of the paper was to offer insights into the interplay between deep learning strategies, perceived self-efficacy, average grades, and subjective well-being among students. The findings reveal that deep learning strategies (DEEP) are a robust predictor of perceived self-efficacy (PSE), which in turn significantly influences average grades (AVEG) and subjective well-being (WB).

The substantial direct effect of DEEP on PSE (path coefficient = 0.83) aligns with previous educational research suggesting that deep learning approaches are closely linked to students' confidence in their learning abilities (Ciolan and Manasia 2017; Panadero et al. 2021). This relationship underscores the importance of educational practices that promote in-depth understanding and critical thinking, as these strategies appear to bolster students' self-efficacy.

Further, the model elucidates the mediating role of PSE between DEEP and the students' academic outcomes (AVEG) and well-being (WB), with indirect effects quantified by path coefficients of 0.17 for both variables. This mediation is in consonance with Bandura's self-efficacy theory (Bandura 2010; Wang et al. 2023; Zyberaj 2022), which posits that self-efficacy beliefs can significantly mediate the impact of learning strategies on performance outcomes (Öztürk 2022; Wang et al. 2023; Zyberaj 2022). Interestingly, the direct path from AVEG to WB (path coefficient = 0.91) suggests that academic performance is a predominant factor affecting students' subjective well-being. This finding contributes to the burgeoning literature on the link between academic achievement and well-being, emphasizing that successful academic performance may play a more critical role in students' subjective well-being than previously recognized (Checa-Domene et al. 2022; Goetz et al. 2021; Wang et al. 2023). The residual variance in DEEP (0.25) suggests that while deep learning strategies are impactful, other variables not included in the model may also play a role in influencing students' self-efficacy. This opens avenues for future research to explore additional factors, such as classroom environment, teaching practices, or individual student characteristics, that may also contribute to the development of deep learning approaches.

Despite the strengths of the present study, there are limitations to consider. For instance, the relatively low variance explained in DEEP could indicate the need for a more comprehensive measurement that captures the full breadth of deep learning strategies. Additionally, while the model accounts for a significant proportion of variance in subjective well-being (0.77), it does not capture the entirety of the construct, pointing to the complexity of well-being and suggesting that future studies should consider other psychological and contextual factors.

In conclusion, the results of this study have important implications for educators and policymakers. By highlighting the central role of perceived self-efficacy in mediating the relationship between deep learning strategies and both academic and well-being outcomes, it becomes evident that interventions aimed at enhancing self-efficacy could be particularly beneficial. Encouraging deep learning strategies may not only boost academic performance but also contribute to the overall well-being of students.

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THE DIRTY LITTLE ROBOT

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Abstract

In a time marked by significant technological progress, the capital market environment is experiencing swift and transformative changes. Central to this transformation is the integration of algorithmic trading, driven by advanced algorithmic robots (algobots) and powered by state-of-the-art artificial intelligence (AI). This article offers an extensive examination of the substantial influence of algorithms and AI on making financial decisions, illuminating the numerous benefits, associated risks, and broader consequences for enhancing investment results. We embarked on an endeavor to create and evaluate a groundbreaking algorithmic trading bot referred to as "The Dirty Little Robot."

Key words: algorithmic trading; cryptocurrency; back-testing; risk management; trading strategies; technical analysis

1. Introduction

In the ever-changing realm of financial markets, the quest for achieving optimal investment performance has served as a catalyst for innovation and adaptation. In their pursuit of navigating the intricate landscape of capital markets, investors have increasingly turned to technology-driven solutions to gain a competitive advantage. One of the most significant advancements in this endeavor has been the ascent of algorithmic trading, which has revolutionized the process of buying and selling financial assets [1].

The domain of portfolio management has held a special fascination for both researchers and practitioners for more than five decades. Portfolio optimization models, rooted in the seminal work of Markowitz [5], employ the mean value of a random variable to assess returns and variance to estimate risk. Markowitz's original model for portfolio selection aimed to minimize risk while ensuring a specified rate of return, aligning with the decision maker's objectives. Sharpe introduced a new model, focusing on systematic risk and the sensitivity of a stock's return to market fluctuations. Numerous papers have proposed diverse techniques for optimizing financial and insurance decision-making processes [10].

In the real world, when addressing the portfolio selection challenge, complete and precise information about the input parameters is not always available [3]. This uncertainty can be attributed to randomness or fuzziness, complicating the specification of random variable distributions and fuzzy number membership functions. This is evident from instances where assigned parameters do not perfectly match real-world scenarios [11].

The term "Algobots" characterizes algorithmic trading systems that have gained rapid prominence in recent years. These sophisticated automated systems leverage cutting-edge algorithms to execute trades swiftly, efficiently, and with precision. Their impact on capital markets has been profound, ushering in a new era of trading that has redefined investment strategies and market efficiency [6].

The origins of algorithmic trading can be traced back to the 1970s and 1980s when early computerized trading systems were introduced. These rudimentary systems executed basic instructions like "buy" or "sell" based on preset conditions, marking the beginning of a technological shift in financial markets [9].

Over the years, algorithmic trading evolved in response to the increasing complexity of financial instruments and market dynamics. The 1990s saw the emergence of more sophisticated algorithms capable of analyzing vast datasets and adapting to real-time market conditions. This period also witnessed the development of electronic communication networks (ECNs), providing fertile ground for algorithmic trading to thrive.

The 21st century brought a data revolution, enhancing the capabilities of algobots. Advances in computing power and the availability of extensive data sources enabled the creation of more intricate trading algorithms. Machine learning and artificial intelligence algorithms entered the scene, allowing algobots to learn from historical data and make predictions about market movements. Additionally, high-frequency trading (HFT) strategies gained widespread adoption, executing trades in microseconds to capitalize on rapid market opportunities [13].

This high-speed trading raised concerns about market stability and fairness, prompting regulatory scrutiny and reform efforts. Algobots have significantly impacted investment strategies by reducing trading costs and introducing precision and consistency. Investors now have access to a variety of algorithmic trading strategies, including trend following, market making, and statistical arbitrage, among others. Moreover, algobots have contributed to market efficiency by narrowing bid-ask spreads, enhancing liquidity, and reducing market anomalies.

However, they have also been associated with market events such as flash crashes, raising questions about their potential to amplify market fluctuations. As algobots continue to evolve and adapt to changing market conditions, their influence on capital markets is poised to expand. This article aims to provide insights into the evolving landscape of algorithmic trading, shedding light on the challenges and opportunities it presents for investors, regulators, and market participants [7]. In this research paper, we initially introduce the fundamental concepts of algorithmic trading, emphasizing its advantages, disadvantages, strategy optimization, and a comparative analysis with human trading. Our approach was centered around the meticulous integration of advanced technical indicators and a comprehensive analysis of price action. Our journey led us to the development and testing of our innovative algorithmic trading bot, named "The Dirty Little Robot."

Our algorithmic trading bot was specifically crafted to excel in the ever-changing landscape of cryptocurrencies, with a particular focus on the Bitcoin/USDT perpetual instrument within the Binance exchange ecosystem. The foundation of our strategy rested on the utilization of the Exponential Moving Average, coupled with a keen evaluation of bullish and bearish engulfing formations. This combination of technical indicators and price action analysis was strategically fine-tuned to precisely identify the market trend following.

2. Literature Review

2.1. Trading Fundamentals: A Comprehensive Guide

Within the realm of financial markets, investors and traders employ a variety of tools and theoretical frameworks to scrutinize asset prices, forecast future movements, and make well-informed choices. Among these tools, technical analysis takes a prominent position. This essay delves into the theoretical underpinnings of technical analysis, encompassing key elements such as the Exponential Moving Average (EMA), Relative Strength Index (RSI), and Bullish and Bearish Engulfing patterns, elucidating how they contribute to a more profound comprehension of market dynamics [2],[7].

The Bedrock of Technical Analysis At its essence, technical analysis involves the art and science of scrutinizing historical price and volume data to anticipate forthcoming price fluctuations. Unlike fundamental analysis, which revolves around an asset's intrinsic value, technical analysis operates on the premise that historical price patterns have a tendency to repeat themselves due to market psychology and human behavior.

Exponential Moving Average (EMA): Capturing Trends The Exponential Moving Average (EMA) holds fundamental significance within the realm of technical analysis. It represents a type of moving average that accords greater weight to recent price data, rendering it more responsive to the current state of the market. EMA calculates the mean of a specific number of price data points over a designated timeframe, attributing more significance to recent price movements. Consequently, EMA possesses the capability to swiftly capture trends in comparison to its counterpart, the Simple Moving Average (SMA).

EMA serves diverse roles within technical analysis. It aids traders in identifying trends, delineating support and resistance levels, and pinpointing potential entry and exit points in the market. An ascending EMA signifies an uptrend, while a descending EMA indicates a downtrend. Additionally, the crossover of shorter and longer-term EMAs can be employed to generate buy or sell signals.

Bullish and Bearish Engulfing Patterns: Signals of Reversal Bullish and Bearish Engulfing patterns constitute candlestick patterns utilized in technical analysis for the identification of potential trend reversals. These patterns emerge from the interplay of two successive candlesticks and are instrumental in gauging market sentiment [7].

A Bullish Engulfing pattern takes shape when a diminutive bearish (downward) candlestick is succeeded by a larger bullish (upward) candlestick that wholly encompasses the prior candle. This configuration implies the potential reversal of a downtrend into an uptrend, signifying the ascendancy of buyers.

Conversely, a Bearish Engulfing pattern materializes when a small bullish candlestick is followed by a larger bearish candlestick that completely engulfs the preceding one. This signals a possible transition from an uptrend to a downtrend, suggesting the ascendancy of sellers.

Both Bullish and Bearish Engulfing patterns afford traders unmistakable visual cues of impending trend reversals, enabling them to make timely decisions in response to evolving market dynamics.

Technical analysis, fortified by tools like EMA, RSI, and candlestick patterns such as Bullish and Bearish Engulfing, furnishes traders with a methodical approach to deciphering price movements and identifying prospective opportunities and risks in financial markets. By delving into these theoretical concepts, traders can attain deeper insights into market psychology and trends, thereby facilitating more informed and strategic trading choices. Although technical analysis is not devoid of criticism, its widespread adoption in the financial industry underscores its enduring relevance and effectiveness in today's dynamic markets [5].

2.2. The Power of Algobots: A SWOT Study

In today's dynamic financial landscape, we witness the ascendancy of algorithmic trading, affectionately known as "algobots," as a dominant force. These intricate automated systems, driven by sophisticated algorithms and data analytics, have fundamentally reshaped the dynamics of trading. This essay embarks on an in-depth exploration of the world of algobots, seeking to unravel their SWOT (Strengths, Weaknesses, Opportunities, and Threats) in a comprehensive manner, shedding light on their multifaceted role within the financial markets [12].

Algobots exhibit a formidable array of strengths that underlie their dominance in modern trading. Chief among these is their exceptional efficiency. Algobots execute trades with astonishing speed, often in mere milliseconds. This rapid execution empowers traders to seize fleeting price differentials and capitalize on arbitrage opportunities that would elude human traders. Additionally, algobots eliminate the inherent lag and potential for manual errors associated with human trading, enhancing overall operational efficiency.

Another compelling advantage lies in their prowess in data processing. Algobots excel in processing vast volumes of data in real-time, seamlessly ingesting and analyzing market news, historical data, and various technical indicators concurrently. This capacity enables them to make data-driven decisions swiftly, a feat that surpasses human capacity [13].

Furthermore, algobots are paragons of consistency. They steadfastly adhere to predefined trading strategies, ensuring a disciplined and uniform approach to trading. This unwavering consistency minimizes the adverse effects of human emotions and biases, which often cloud the judgment of traders.

The ability to rigorously backtest trading strategies represents another potent asset. Algobots can undergo extensive backtesting on historical data, enabling traders to refine and optimize their algorithms, thereby enhancing their potential for peak performance.

Nonetheless, algobots are not without their weaknesses. Foremost among these is their inherent lack of adaptability. Algobots are designed to execute predetermined strategies with limited room for flexibility. They may struggle to navigate unforeseen market events or rapidly changing conditions that necessitate human judgment and adaptability, potentially continuing to execute predefined strategies even when they become ineffective or counterproductive.

Furthermore, algobots are susceptible to technical vulnerabilities. Despite their computational prowess, they are not immune to technical glitches or connectivity issues. A minor malfunction can swiftly translate into unexpected losses, underscoring the importance of vigilant oversight and safeguards [6].

The third weakness revolves around their complexity. Developing and maintaining algorithmic trading systems of the highest caliber demands a profound level of technical expertise and substantial resources. The intricacy of these systems may deter smaller traders and investors who lack the requisite technical acumen and resources.

On the flip side, algobots open doors to a myriad of opportunities in the financial landscape. Their role in democratizing market access is particularly noteworthy. By automating trading processes, algobots provide market access to a broader spectrum of traders, including individuals who would otherwise be deterred by the complexities of manual trading.

Furthermore, the prevalence of algobots has sparked heightened interest in quantitative analysis and data science. Opportunities for professionals in these fields have surged, as the demand for quantitative analysts, data scientists, and algorithm developers continues to escalate in response to the rise of algobots.

Moreover, the continuous evolution of algorithmic trading strategies offers fertile ground for traders and software developers to innovate and create algorithms that can outshine competitors. This ever-evolving landscape invites proactive exploration and experimentation [6],[7].

Nonetheless, algobots are not without their share of threats. One notable threat arises from the specter of regulatory changes. As algorithmic trading continues to gain prominence, regulatory bodies have intensified their scrutiny of this domain. The imposition of stricter rules and regulations may impact the viability of algobots and escalate compliance costs.

Another peril revolves around the potential for market manipulation. The sheer speed and volume at which algobots operate can inadvertently provide a fertile ground for market manipulation. Flash crashes and other market irregularities pose a palpable threat to market stability, necessitating constant vigilance and monitoring.

Lastly, there is the lingering concern of human displacement. The widespread adoption of algobots may lead to job displacement in the financial industry, particularly among human traders and analysts. The automation of trading processes raises questions about the future role and relevance of human expertise in financial markets [12].

Algorithmic trading, embodied by the enigmatic algobots, embodies a double-edged sword in the world of finance. Their strengths, encompassing unmatched efficiency, data-processing prowess, unwavering consistency, and the potential for meticulous backtesting, have propelled them to the forefront of modern trading. However, they must grapple with the weaknesses of adaptability challenges, technical vulnerabilities, and inherent complexity.

The opportunities that algobots present are marked by expanded market access, burgeoning interest in quantitative analysis and data science, and a fertile ground for the development of innovative trading strategies. Nevertheless, they must contend with threats such as regulatory changes, market manipulation risks, and concerns about job displacement.

As algobots continue to evolve and integrate deeper into financial markets, striking a harmonious balance between human judgment and algorithmic precision remains imperative. Traders and investors who navigate this intricate landscape adeptly will be well-poised to harness the strengths of algobots while mitigating their weaknesses. They must also remain vigilant in seizing the opportunities that lie ahead while addressing the threats that accompany this transformative era in the financial industry.

In the realm of financial markets, two distinct approaches have taken shape over time: human trading and algorithmic trading. The former relies on human intuition, experience, and emotions, while the latter harnesses complex computer programs to execute trades with speed and precision. This essay delves into the fundamental distinctions, advantages, and disadvantages of these two trading methods, emphasizing the critical importance of finding a harmonious balance between them in today's dynamic financial landscape.

Human trading is characterized by individual traders who make buy and sell decisions based on their judgment, analysis, and market expertise. This approach is inherently subjective, as it relies on human intuition and emotions. Human traders possess unique advantages. They can interpret market news, sentiment, and global economic conditions effectively, adapting to rapidly changing market dynamics. Additionally, experienced human traders often develop an invaluable "gut feeling" for market movements, shaped by years of insights and strategies.

However, human trading also carries its share of disadvantages. Emotional biases, such as fear and greed, can lead to impulsive decisions, overtrading, or holding onto losing positions. Furthermore, humans cannot match the speed of computers, resulting in slower execution times and missed opportunities in high-frequency trading environments. Continuous monitoring of financial markets can also lead to stress and fatigue, which can impact decision-making and overall well-being.

Algorithmic trading, also known as algo trading or automated trading, relies on computer algorithms to execute trades based on predefined criteria. These algorithms are designed to process vast amounts of data and execute orders swiftly and precisely. The advantages of algorithmic trading are notable. Algorithms can execute trades within milliseconds, enabling traders to capitalize on price discrepancies and arbitrage opportunities. They eliminate emotional biases, ensuring that decisions are grounded solely in data and logic. Additionally, algorithmic systems can maintain discipline and consistency in executing trading strategies, reducing the risk of human error. They can also be backtested on historical data to assess performance, allowing for optimization and fine-tuning [2].

Nonetheless, algorithmic trading also has its disadvantages. Algorithms may struggle to adapt to unforeseen events or rapidly changing market conditions that require human judgment. Moreover, these systems can be vulnerable to technical glitches or connectivity problems that may result in unexpected losses.

In today's financial markets, achieving a balance between human and algorithmic trading is crucial. Both approaches have their unique strengths and weaknesses, and combining them can lead to superior results. Many institutional traders employ hybrid strategies that blend human expertise with algorithmic execution. In these approaches, human traders provide qualitative insights and adaptability, while algorithms handle the execution and quantitative aspects. Human traders can also oversee and manage algorithmic systems to ensure they align with the market's current dynamics and mitigate unexpected risks [1].

Furthermore, traders should continually update their skills and understanding to remain competitive in an increasingly automated world. Human trading and algorithmic trading represent two distinct yet complementary approaches to navigating the complexities of financial markets. Striking a balance between human intuition and algorithmic efficiency is essential for success in today's rapidly evolving trading environment. Traders who embrace this duality are likely to be better equipped to harness the strengths of both methods and adapt to the ever-changing landscape of financial markets.

2.3. The Art and Science of Algorithmic Trading

In the realm of algorithmic trading, the rapid and effective development, testing, and deployment of trading strategies are of utmost importance. TradingView, a widely embraced charting platform among traders and investors, serves as a valuable resource for this purpose, thanks to its versatile scripting language known as Pine Script. Recently, with the introduction of Pine Script 5, TradingView has elevated the capabilities of algorithmic trading to new heights, providing enhanced functionality and utility for the creation of advanced algobots.

TradingView is renowned as an online platform highly respected for its robust charting tools and technical analysis features. Traders and investors flock to TradingView to analyze financial markets, conduct research, and make well-informed decisions. The platform's user-friendly interface and extensive library of indicators have made it a preferred choice for both newcomers and seasoned market participants. However, the true strength of TradingView lies in its scripting language, Pine Script. Pine Script empowers users to develop custom indicators, strategies, and alerts, unlocking the potential for algorithmic trading and tailored technical analysis. With the advent of Pine Script 5, TradingView has made significant advancements in refining this scripting language, providing traders with a powerful toolkit for the creation and execution of algobots [14],[15].

Pine Script 5 represents a substantial evolution in the capabilities of TradingView's scripting language. This latest version introduces several noteworthy features and enhancements that are invaluable for algorithmic traders. It embraces the principles of object-oriented programming (OOP), which enhances code organization and reusability while streamlining the development process. Moreover, Pine Script 5 is engineered for improved performance, featuring faster execution times and reduced memory consumption, enabling it to handle complex strategies and calculations efficiently. Additionally, Pine Script 5 offers advanced data handling capabilities, allowing traders to work with multiple data series concurrently. This is particularly beneficial when developing strategies that require the analysis of multiple assets or timeframes. Pine Script 5 also incorporates a range of built-in functions, simplifying intricate calculations and reducing the reliance on external libraries [14],[15].

The utility of Pine Script 5 for developing algobots is undeniable. Algorithmic trading strategies demand a robust environment for development and testing, and TradingView's platform, coupled with Pine Script 5, provides precisely that. Pine Script 5's intuitive syntax and comprehensive documentation facilitate the rapid prototyping of trading strategies, allowing traders to iterate and fine-tune their algobots quickly. The platform also offers a comprehensive backtesting environment, enabling traders to rigorously test their algorithms on historical data. Pine Script 5's performance enhancements ensure faster and more accurate backtesting.

Moreover, traders can seamlessly deploy their algobots in real-time directly from TradingView, streamlining the transition from development to live trading.TradingView's community comprises a vibrant ecosystem of traders and developers who openly share Pine Script code, indicators, and strategies, fostering collaboration and significantly expediting algobot development. In essence, Pine Script 5, in conjunction with TradingView, has emerged as a formidable tool for traders and developers venturing into the world of algorithmic trading. With Pine Script 5's versatility and TradingView's user-friendly platform, traders have at their disposal a potent combination for developing, testing, and deploying trading strategies. Whether one is a seasoned algorithmic trader or a newcomer to the field, Pine Script 5 and TradingView offer an enticing gateway to the exciting and potentially lucrative realm of algobots [14],[15].

3. Methodology

This article delves into the development and evaluation of an algobot known as "Dirty Little Robot" (DLR), which was created using Pine Script 5 on the TradingView platform. The primary objective of this algobot is to execute trading strategies specifically tailored for the BTC/USDT Perpetual trading pair on the Pionex exchange, with a focus on a 1-minute time frame and an 11-day backtesting period.

DLR implements a trend-following strategy that relies on identifying bullish and bearish engulfing candlestick patterns in conjunction with the Exponential Moving Average (EMA) 200. When a bullish engulfing pattern is identified above the EMA 200, the algobot initiates a long position. Conversely, when a bearish engulfing pattern forms below the EMA 200, it takes a short position.

A critical aspect of DLR's strategy is its adherence to a risk/reward ratio of 3:1. This means that the take profit level is set at 1.2% of the trading pair's value, while the stop loss level is positioned at 0.4%. This risk management approach plays a pivotal role in controlling potential losses and optimizing gains. To assess the performance of DLR, a comprehensive backtesting process was conducted using the TradingView Strategy Tester. Historical price data for the BTC/USDT Perpetual trading pair on the Pionex exchange served as the basis for this evaluation. The backtesting period encompassed a significant timeframe, allowing for a thorough examination of the algobot's effectiveness.During the backtest, the algobot executed trading signals, including entry and exit points, within a simulated environment based on historical data. This enabled the measurement of profitability, risk exposure, and overall performance.

The subsequent section of this article will delve into the detailed implementation of the algobot on the Pionex exchange. Additionally, it will analyze and present the results obtained from the backtesting procedure to determine the viability of the algobot in real-world trading scenarios. The study aims to provide insights into the effectiveness of the DLR strategy within the highly volatile cryptocurrency market, highlighting its potential to generate consistent returns while effectively managing risk.

4. Development Process

The successful development of algorithmic trading strategies for the Dirty Little Robot (DLR) paved the way for their implementation on the Pionex exchange. The integration process was accomplished by leveraging TradingView's strategy alerts, which were seamlessly linked to the Pionex platform through a webhook connection. This integration facilitated the automatic execution of trading signals generated by DLR on the exchange, allowing for real-time trading based on the predefined strategies.

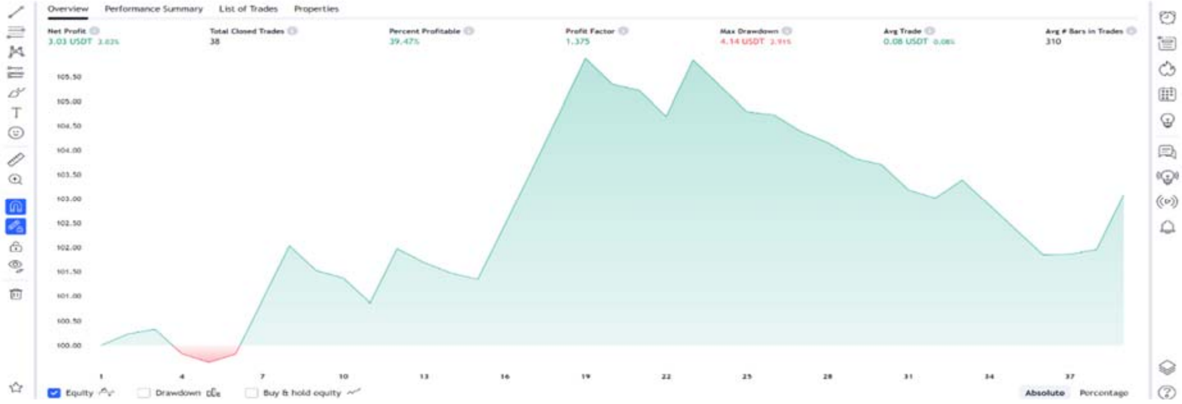

Figure 3. Results from DLR
Source: Tradingview Platform

Figure 4. Long trade made by DLR
Source: Tradingview Platform

DLR, also known as the Dirty Little Robot, has displayed impressive results during backtesting, particularly when applied to trending markets. Its strategy, which relies on the identification of bullish and bearish engulfing patterns alongside the EMA200 indicator, yielded a commendable net profit of 3.03% over an 11-day evaluation period.

With a win rate of 39.47% and a profit factor of 1.375, DLR showcases its potential to consistently generate profits in markets characterized by prolonged trends.

Analyzing DLR's performance underscores its proficiency in effectively recognizing and capitalizing on well-established trends. By utilizing engulfing patterns as signals for both entry and exit, DLR adheres to a systematic approach that harmonizes with its trend-following strategy. This analysis emphasizes its suitability for traders aiming to participate in extended price movements.

Implementation of Dirty Little Robot (DLR):

DLR's implementation involved the application of a trend-following strategy, where specific criteria triggered trade execution. For long positions, DLR identified the presence of a bullish engulfing candlestick pattern in conjunction with the closing price being above the Exponential Moving Average (EMA) 200. Conversely, for short positions, the occurrence of a bearish engulfing pattern along with the closing price being below the EMA 200 initiated trade execution.

Results of Backtesting for DLR:

The effectiveness of DLR was rigorously evaluated through backtesting, which simulated its performance over an 11-day period on the Pionex exchange, using the BTC/USDT Perpetual trading pair. The backtesting results offer valuable insights into the strategies' viability and their potential to generate profits.

DLR Backtesting Results:

- Net Profit: 3.03%
- Total Closed Trades: 38
- Win Rate: 39.47%
- Profit Factor: 1.375
- Average Trade Profit: $0.08
- Average Win-to-Loss Ratio: 2.1

The backtesting results for DLR reveal a positive net profit of 3.03% achieved during the 11-day testing period. DLR executed a total of 38 closed trades, achieving a win rate of 39.47%. The profit factor, which measures the ratio of winning trades to losing trades, stands at 1.375, indicating the strategy's effectiveness in generating profits. On average, each trade yielded a profit of $0.08, with a favorable average win-to-loss ratio of 2.1.

Interpretation of the pine script code and limitations

The Pine Script code for "Didy Little Robot"

```
//@version=5
strategy("Dirty Little Robot", overlay = true)
//EMA
ema200 = ta.ema(close, 200)
//Candlestick Patterns
C_EngulfingBullish () =>
   close[1] < open[1] and
   open < close and
   close > open[1] and
   open < close[1]
C_EngulfingBearish () =>
   close[1] > open[1] and
   open > close and
   close < open[1] and
   open > close[1]
// Strategy Entry
long_condition = C_EngulfingBullish and close > ema200
short_condition = C_EngulfingBearish and close < ema200
if (long_condition)
   strategy.entry("Long", strategy.long)
if (short_condition)
   strategy.entry("Short", strategy.short)
//Strategy exit
stopLossPercent = 0.004
```

```
takeProfitPercent = stopLossPercent * 3
var float stopLossPrice = na
var float takeProfitPrice = na
if (strategy.position_size > 0)
    stopLossPrice := strategy.position_avg_price * (1 - stopLossPercent)
    takeProfitPrice := strategy.position_avg_price * (1 + takeProfitPercent)
    strategy.exit("Take Profit/Stop Loss", stop = stopLossPrice, limit = takeProfitPrice)
if (strategy.position_size < 0)
    stopLossPrice := strategy.position_avg_price * (1 + stopLossPercent)
    takeProfitPrice := strategy.position_avg_price * (1 - takeProfitPercent)
    strategy.exit("Take Profit/Stop Loss", stop = stopLossPrice, limit = takeProfitPrice)
```

Analyzing the Pine Script for "Dirty Little Robot"

Algorithmic trading strategies have gained popularity for their systematic and data-driven approach to financial market trading. The presented Pine Script represents one such strategy called "Dirty Little Robot." Crafted in Pine Script 5, a potent scripting language integrated into the TradingView platform, this code enables the creation of customized trading strategies. Let's explore this script to grasp its structure and functionality.

The script begins with a script header, a crucial component of any Pine Script. It starts with the declaration `//@version=5`, indicating that the code is written in Pine Script version 5. The strategy is named "Dirty Little Robot" and is configured to overlay on the price chart, making its signals and actions visible to traders.

Technical indicators play a pivotal role in algorithmic trading, aiding in market data analysis. In this script, the Exponential Moving Average (EMA) with a 200-period setting is calculated based on the closing prices of the asset being analyzed. This EMA serves as a reference point for trend analysis, a critical aspect of trading.

The script introduces flexibility by offering users two trend detection rules. These rules, named "SMA50" and "SMA50, SMA200," allow traders to choose their preferred method of identifying trends. This choice is fundamental in determining the direction of potential trades.

Candlestick patterns are foundational in technical analysis for trading. The script incorporates various variables to define and detect these patterns, including engulfing patterns and doji patterns. Recognizing these patterns is crucial for identifying potential entry and exit points in the strategy.

To enhance the user experience, the script allows customizable labeling of detected candlestick patterns on the chart. Users can select label colors, adding a personal touch to their trading environment.

The crux of the strategy revolves around detecting engulfing patterns, both bullish and bearish. These patterns are pivotal in determining when to initiate or close a trade. The script employs specific conditions to identify these patterns and generate alerts when they occur.

After pattern detection, the script delves into the core of the strategy – entry and exit conditions. It defines the logic for entering long or short positions based on the detected candlestick patterns and the relationship between the current price and the EMA200.

Effective risk management is a cornerstone of successful trading. To address this, the script includes logic for setting stop loss and take profit levels. These levels are essential for controlling potential losses and locking in profits at predefined levels.

In summary, "Dirty Little Robot" is a comprehensive algorithmic trading strategy developed in Pine Script 5. It seamlessly combines trend analysis, candlestick pattern recognition, and risk management to execute precise trading decisions. This script offers traders, whether experienced or novice, a versatile framework for creating and testing trading strategies within the TradingView platform.

Limitations:

One drawback of this study pertains to the relatively brief backtesting duration, which spans only 11 days. While the outcomes gleaned from this period provide valuable insights, they may not comprehensively reflect the long-term capabilities of the algobots. Historical data, which serves as the basis for backtesting, might not perfectly mirror future market conditions, introducing an element of uncertainty. There's also the risk of overfitting, where algobots become overly tailored to historical data, potentially leading to suboptimal performance in live markets. Given the evolving nature of market dynamics, certain strategies may lose their effectiveness over time. It is essential to continuously monitor and adapt algobots to ensure they remain in sync with prevailing market conditions.

Moreover, external factors, such as sudden news events or market manipulations, have the potential to influence algobot performance. These external influences are notoriously challenging to predict and integrate into algorithmic models, placing constraints on the algobots' effectiveness. Execution speed and market liquidity can significantly impact algobot performance, especially in high-frequency trading scenarios. Delays in executing trades or trading in assets with limited liquidity can markedly affect outcomes. Traders must ensure that their chosen trading platform provides the necessary infrastructure for efficient execution.

The discussion, interpretation, and acknowledgment of limitations associated with DLR algobot provide valuable insights for traders contemplating algorithmic trading strategies. This algobot undoubtedly exhibit strengths in systematic trading, risk management, and adaptability to diverse market conditions. Nevertheless, it is prudent for traders to remain cognizant of these limitations, including the relatively short backtesting period, the risk of overfitting, and the influence of external factors. When harnessed thoughtfully and continually adjusted, algorithmic trading can furnish a robust framework for effectively navigating the dynamic terrain of financial markets.

5. Conclusions and Future Research

In conclusion, this article has provided an in-depth exploration of the development, evaluation, and implementation of the "Dirty Little Robot" (DLR) algobot. DLR was meticulously crafted using Pine Script 5 on the TradingView platform, with a specific focus on executing trading strategies tailored for the BTC/USDT Perpetual trading pair on the Pionex exchange. The strategy employed by DLR centers around the identification of bullish and bearish engulfing candlestick patterns in conjunction with the Exponential Moving Average (EMA) 200. Throughout the article, we've delved into various facets of DLR's journey, including its backtesting results, performance analysis, and the intricacies of its Pine Script code.

The results of the backtesting process demonstrated DLR's ability to generate a commendable net profit of 3.03% over an 11-day evaluation period. With a win rate of 39.47% and a profit factor of 1.375, DLR showcases its potential for consistent profitability, particularly in markets characterized by sustained trends. We've also taken a closer look at the Pine Script code, which serves as the foundation for DLR's functionality.

This script incorporates key elements such as trend analysis, candlestick pattern recognition, and risk management, providing traders with a versatile framework for developing and testing trading strategies within the TradingView platform.

In the realm of algorithmic trading, where data-driven precision meets systematic execution, DLR stands as a testament to the potential for automated strategies to navigate the dynamic and often volatile landscape of financial markets. It underscores the importance of rigorous testing and risk management in algorithmic trading endeavors. While the article highlights DLR's strengths, it's crucial to remain mindful of its limitations, including the relatively short backtesting period and the influence of external factors.

Algorithmic trading, when approached thoughtfully and continuously adapted, can indeed offer a robust framework for navigating financial markets effectively. Traders and investors who leverage the power of algorithmic strategies while staying vigilant and adaptable are well-positioned to harness the opportunities presented by this dynamic and ever-evolving field.

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